DEPARTMENT OF COMMERCE

TECHNOLOGIC PAPERS

OF THE

BUREAU OF STANDARDS

S. W. STRATTON, DIRECTOR

No. 74

INVESTIGATION OF CARTRIDGE-INCLOSED FUSES

REPORT OF THE BUREAU OF STANDARDS IN THE CASE OF ECONOMY FUSE & MANUFACTURING CO. *v.* UNDERWRITERS' LABORATORIES (INC.), CONCERNING THE FIRE AND ACCIDENT HAZARD OF THE ECONOMY REFILLABLE FUSE AS COMPARED WITH APPROVED FUSES

BY BOARD OF REFEREES:

E. B. ROSA, Chief Physicist
H. B. BROOKS, Associate Physicist
BURTON McCOLLUM, Electrical Engineer
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and
F. W. GLADING, Associate Electrical Engineer
Bureau of Standards

ISSUED DECEMBER 1, 1916

WASHINGTON
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PREFACE

The following report represents the results of the investigation carried out by the Bureau of Standards acting as referee on the joint request of the Economy Fuse & Manufacturing Co. and Underwriters' Laboratories (Inc.) on the question of the relative fire and accident hazard of Economy refillable fuses and fuses at present listed as standard by Underwriters' Laboratories (Inc.).

The evidence on which the decision was based includes a large number of tests of fuses under widely different conditions, as well as inspections of numerous fuse installations in practice, personal interviews with many fuse users, evidence and arguments submitted by the Economy Fuse & Manufacturing Co. and Underwriters' Laboratories (Inc.), both at a public hearing and by correspondence, and evidence and arguments submitted by a number of manufacturers of fuses at present listed as standard by Underwriters' Laboratories (Inc.).

The question was carefully considered in its various aspects by a committee of technical experts of the Bureau of Standards and has been decided on the technical questions at issue.

S. W. STRATTON,
Director.

WASHINGTON, D. C., *February 21, 1916.*

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REPORT OF THE BUREAU OF STANDARDS IN THE CASE OF ECONOMY FUSE & MANUFACTURING CO. VS. UNDERWRITERS' LABORATORIES (INC.) CONCERNING THE FIRE AND ACCIDENT HAZARD OF THE ECONOMY REFILLABLE FUSE AS COMPARED WITH APPROVED FUSES

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INTRODUCTION

There exists a permanent arrangement between the Underwriters' Laboratories (Inc.), of Chicago, Ill., and the Bureau of Standards whereby in the event of dispute between the Underwriters' Laboratories and the manufacturer of any device submitted to them for approval, the dispute may, with the consent of both parties, be submitted to the Bureau of Standards for decision.

In accordance with this arrangement the Underwriters' Laboratories and the Economy Fuse & Manufacturing Co., of Chicago, Ill., jointly appealed, under date of May 17, 1915, to the Bureau of Standards for decision on the following question:

Has it been shown that the use of the fuses manufactured by the Economy Fuse & Manufacturing Co. results in no greater fire or accident hazard than the use of other cartridge-inclosed fuses at present listed as standard by Underwriters' Laboratories (Inc.)?

SCOPE OF THE INVESTIGATION

1. *Time Allowed for Submission of Evidence.*—It was originally agreed that all of the evidence in the case must be presented not later than July 23, 1915—15 days after the formal hearing which was to be held at the Bureau on July 8. This date was later changed to October 15, at the formal request of the manufacturers of approved fuses, in order that they might have more opportunity to secure and present to the Bureau of Standards additional evidence bearing on the case.

2. *Character of Evidence Obtained.*—At the outset of the investigation of this question a considerable amount of evidence was submitted to the Bureau by both the Underwriters' Laboratories and the Economy Fuse & Manufacturing Co. On July 8, 1915, a

public hearing was held at the Bureau of Standards, notices of which were sent out under date of June 10. At this hearing evidence and arguments were presented by representatives of the Underwriters' Laboratories, the Economy Fuse & Manufacturing Co., and by a number of companies manufacturing approved cartridge fuses.

In addition to the evidence presented at the hearing the Bureau of Standards made a large number of tests of inclosed fuses, some in its own laboratories and others at large power plants in other cities. A majority of these tests were made in accordance with the specifications of the Underwriters' Laboratories, but a considerable number were made under other conditions prescribed by the Bureau or suggested by fuse manufacturers.

The chief objects of these tests were to determine the relative performance on heavy overloads of new and refilled Economy fuses and approved cartridge fuses as supplied by manufacturers or by jobbers; and further, to determine to what extent the performance of such fuses might be deleteriously affected by protracted service under normal conditions in the customers' cut-outs.

A great deal of attention has also been given to the question of the actual use of Economy and of approved fuses, and the experience of a great many users of fuses was obtained by correspondence and by inspectors of the Bureau of Standards, who personally visited a great many installations where fuses of approved makes as well as fuses of the Economy company were in use. Special attention was given to the possibilities of the dangerous misuse and the extent of observed misuse both of Economy fuses and of approved types of inclosed cartridge fuses.

PRELIMINARY EVIDENCE SUBMITTED BY THE UNDERWRITERS' LABORATORIES

The preliminary evidence submitted by the Underwriters' Laboratories prior to the hearing indicated a fairly satisfactory test performance of new Economy fuses, although a large proportion of the tests reported on were made with earlier types of the Economy fuse, which differed radically from the fuse at present in use. In general, the Economy fuse opened the circuit more promptly on a moderate overload than most of the approved fuses, and the evidence submitted by the Underwriters' Laboratories indicated that the performance of the 250-volt fuses on short-circuit tests was satisfactory, although certain of the 600-volt type were reported as having failed. It appeared, therefore, that the reason why the Under-

writers' Laboratories withheld approval of the 250-volt Economy fuses was because this fuse is designed to be readily refilled by the user, and it has been consistently held by the electrical committee of the National Fire Protection Association that fuses of this character should not be approved, because of the greater probability of misuse of such fuses in service than of fuses that are difficult to refill by the user.

PRELIMINARY EVIDENCE SUBMITTED BY THE ECONOMY FUSE & MANUFACTURING CO.

The evidence submitted by the Economy Fuse & Manufacturing Co. prior to the formal hearing in Washington consisted in large part of the opinions of users of fuses and of inspectors who have had considerable knowledge of the use of Economy fuses. The opinions of users of fuses were obtained chiefly by the medium of circular letters sent out by the Economy Fuse & Manufacturing Co. requesting answers to stated questions.

There were also submitted by the Economy Fuse & Manufacturing Co. samples of various makes of approved fuses, for the purpose of demonstrating the ease with which such fuses could be refilled by the user, notwithstanding the fact that they are intended not to be so used. A number of affidavits by prominent inspectors expressing opinions favorable to the Economy fuse were also submitted.

The general trend of all of the testimony submitted in advance by the Economy Fuse & Manufacturing Co. appeared to be decidedly favorable to the Economy fuse, although even among regular users of these fuses the experience was not uniformly satisfactory. In interpreting this favorable testimony, however, it should be borne in mind that it can not be accepted without reserve as exemplifying the experience or opinions of all users of fuses. The mere fact that these companies are using Economy fuses is sufficient to place them in a select class, which might very naturally be expected to express favorable opinions regarding the use of these fuses. Hence, before these opinions can be accepted as reflecting the general trend of opinion among fuse users it is necessary to take into account the fact that many users may have at one time or another considered the use of Economy fuses, but refrained from using them for reasons which they deemed sufficient and which it would be impossible to get into the record of the present case. Furthermore, firms using fuses not listed as standard in insured properties would very naturally be reluctant

to give any evidence tending to show that they were incurring an appreciable hazard in so doing, even though events may have occurred which would lead the users themselves to expect a possible increase in the hazard. We must therefore consider the possibility that in certain cases the statements may not accurately reflect the opinions of the users themselves. In certain cases, too, the evidence submitted does not bear out the expressed opinion that the performance of the fuses in service has been satisfactory.

Specimens of approved fuses submitted to the Bureau by the Economy Fuse & Manufacturing Co. and others show quite clearly that many such fuses can readily be refilled by the users, and that refilling both with the proper fuse elements and with improper elements is actually done to a considerable extent has been clearly shown by the investigations made by the inspectors of the Bureau of Standards.

The letters from inspection departments and affidavits from inspectors presented by the Economy Fuse & Manufacturing Co. are all very favorable to the use of Economy fuses, and on their face would appear to convey beyond question the idea that the authors of the statements are convinced that not only have Economy fuses proved satisfactory in use up to the present time, but that there is no reason why they should not be formally approved by the Underwriters.

HEARING AT THE BUREAU OF STANDARDS

At the formal hearing held at the Bureau of Standards on July 8, 1915, the Economy Fuse & Manufacturing Co. again presented in brief form the evidence it had already submitted in advance. A representative of the Underwriters' Laboratories presented an argument on behalf of the Laboratories, in which was set forth briefly the history of the development of the Economy fuse, and it was pointed out that several radical changes had been made in its construction since its advent three years ago. In this argument it was admitted that a good deal of favorable experience has been had with Economy fuses, but it was shown that the greater part of the experience read into the record had been gained with the older type of fuse which contained powdered filler and could not, therefore, be held to apply to the type of fuse at present being manufactured by the Economy Fuse & Manufacturing Co. No attempt was made to show that the fuse at present made was not a good fuse, but it was contended that the

present form of fuse, which had been in use only a few months, had not yet afforded sufficient service experience to prove whether its use would, with lapse of time and increase in numbers, result in an increase of the hazard which is incident to the use of approved fuses. Various representatives of manufacturers of approved fuses set forth at some length the dangers which they held would be likely to result from improper use of refillable fuses in practice, and took the position that not only Economy fuses but all fuses designed to be refilled by the user should not be approved by the Underwriters' Laboratories.

RESULTS OF THE TESTS ON FUSES

Three extended series of fuse tests were carried out by the Bureau of Standards under short-circuit conditions of widely varying degrees of severity. The first of these series of tests was made at the laboratories of the Bureau of Standards, the second was made at one of the power plants of the Boston Edison Co. in Boston, and the third was made in a plant of the Commonwealth Edison Co. in Chicago. In these tests the performance of the Economy fuse was compared with that of six makes of approved cartridge fuses.

1. *Interpretation of Results of Tests.*—In these tests the performance of the fuses was judged by the proportion of failures in a given number of each type tested and also by the character of the failure that occurred. In interpreting the results of these tests six types of fuse failure were recognized, as follows: (*a*) Rupture of fiber cartridge, (*b*) blowing off of cap or blowing out of end, (*c*) mechanical injury to cut-out, (*d*) ignition of cotton placed around the fuse, (*e*) holding of the arc for an appreciable length of time, and (*f*) remaking of the circuit after it had once been opened by the fuse. Such phenomena as loud report, failure to indicate, excessive scattering of filler, movement of caps, and scorching of cotton, while recognized as objectionable, have not been regarded as evidences of failure in the performance of the fuses. A very violent report, however, has been considered as a serious objection because of the possibilities of panics following such violent operation of the fuses. It is also recognized that certain of the types of failures listed above are much more serious than others, and due consideration has been given to this point in judging the relative performance of the fuses. The energy consumption of the fuses when blowing was measured by means of a watt-meter used ballistically.

2. *Tests at the Bureau of Standards.*—The first series of tests was made in the laboratories of the Bureau of Standards under very mild short-circuit conditions. The limiting current in these tests was from 400 to 800 amperes, and the fuses tested under these conditions were all in the cartridge of the 30-ampere 250-volt dimensions.

In general, the results of the tests under these very mild short-circuit conditions were favorable to the Economy fuse, except where relatively high inductance existed in the circuit. It was found that the energy consumption of the Economy fuses was, in general, much smaller than that of approved fuses, indicating a quicker operation, which was later verified by means of oscillograms. This quicker operation is in some respects an advantage and in other respects a disadvantage. Because of the shorter duration of the flash it reduces the liability of serious burns to persons who may accidentally make short circuit with tools or other metallic objects. It also, for the same reason, reduces the fire hazard at the point of short circuit. The quicker operation is, however, accompanied by a higher electromotive force of self-induction, which often gives a voltage across the line of two or three times the normal voltage, thereby introducing a danger of breakdown of insulation with the accompanying possibility of short-circuit back of the fuse cut-out, which may introduce hazards that will, in large measure at least, offset the benefits of quick operation. On highly inductive circuits, however, on which the ratio of the 60-cycle reactance to the resistance was between 3 and 5 to 1, the performance of the Economy fuses was quite unsatisfactory, even on these small limiting currents, a considerable proportion of the cartridges being exploded on the test. In the case of direct-current circuits, in which motors and magnet coils and similar inductive apparatus are used, and also in case of supply lines run in separate iron conduits, as is sometimes done, these high inductances might often be encountered in practice, so that the failures of the Economy fuses on these mild short-circuit tests might very reasonably be taken as a significant index to their performance in many cases under service conditions.

3. *Boston Fuse Tests.*—The second series of tests made by the Bureau of Standards was carried out at one of the power plants of the Boston Edison Co., these tests being made on 250-volt fuses. In these tests the performance of the Economy fuses was compared with that of six different makes of approved inclosed-cartridge fuses.

4. *Circuit Conditions During Tests.*—These tests were made under three different circuit conditions, in the first two of which the limiting current was about 10 000 amperes, the difference being that under the first circuit condition the inductance of the circuit was 0.186 millihenry, whereas in the second circuit condition it was reduced to a minimum value by placing the leads as close together as practicable, the inductance in this case being 0.11 millihenry. In the third circuit condition the limiting current was reduced to about 5500 amperes, having an inductance of 0.166 millihenry.

Under both the first and second circuit conditions the performance of the Economy fuses in the knife-blade types was in all cases inferior to that of the approved fuses. In the ferrule type the Economy fuses were inferior to five of the approved makes of fuses, but definitely superior to one of the six makes.

Under the third circuit condition, in which the limiting current was reduced to about 5500 amperes, all fuses, including the Economy, behaved in a satisfactory manner, except that in a few cases the blowing of one of the approved makes of fuses was accompanied by rather loud reports.

The tests referred to above were all made with a single fuse on a 250-volt circuit, according to the conditions prescribed by the Underwriters' Laboratories. A series of tests was also made in which two fuses were placed in series on 250-volt circuits, the limiting current being 10 000 amperes. In this series all fuses, including the Economy fuse, behaved in a satisfactory manner.

5. *Chicago Fuse Tests.*—The third series of fuse tests was made at one of the plants of the Commonwealth Edison Co., of Chicago. These tests were for the most part made on 600-volt fuses with only a single fuse in the circuit. Two separate circuit conditions were used, in the first of which the resistance in the circuit varied considerably because of the high initial internal resistance of the battery, which gradually fell off as the test proceeded. In this series the limiting current varied from about 10 000 amperes in the beginning to approximately 18 000 amperes at the end, the circuit inductance being 0.224 millihenry. The resistance of the circuit was then readjusted to give a limiting current of 10 000 amperes, and it remained fairly constant throughout the second series of tests.

This changed the inductance to 0.305 millihenry. In both these series of tests the performance of Economy fuses in the knife-blade type in general proved inferior to that of all of the approved

fuses judged on the relative percentage of failures. However, one type of approved fuse gave rise to three cases of what was considered to be the most serious type of failure, namely, the remaking and sustaining of the circuit after it had first been opened by the fuse. This type of failure did not occur in the Economy fuse, although the oscillograms showed that in a few cases there was a remaking of the circuit for a few thousandths of a second and in one case for a few tenths of a second.

In the ferrule types tested in these two series there was not much choice between the Economy fuse and several makes of approved fuses, although three types of approved fuses were distinctly superior to the Economy fuse. In the 60-ampere size the Economy fuse behaved much worse than any others, while in the 30-ampere size it was distinctly superior to several makes of approved fuses and the equal for any tested.

6. *Tests on "Aged" Fuses.*—A number of short-circuit tests were made on fuses that had carried their rated current for a considerable time, and these tests gave somewhat conflicting results. A considerable number of both Economy and D. & W. fuses were tested that had been submitted by the D. & W. Fuse Co. which were stated to have carried their rated current for periods ranging from 17 to 50 hours. The Economy fuses supplied by the D. & W. Co. gave a very bad performance and showed marked evidence of charring and weakening of the fiber, whereas the D. & W. fuses showed no deterioration. Economy fuses subjected by the Bureau of Standards to their rated current for a period of from 95 to 100 hours showed, however, no appreciable evidence of deterioration in the 30-ampere size. With the 60-ampere size the performance of these fuses was much worse than in the new fuses, but the deterioration was by no means as great as in the case of the fuses supplied by the D. & W. Co. The difference in results was due no doubt, in part at least, to the difference in the grade of the fiber used in the manufacture of the fuses. Four 200-ampere Economy fuses were tested after having been aged on rated current for 51 hours at the Bureau of Standards, and two of these exploded violently. These were the only failures of the 250-volt Economy fuses in the 200-ampere size. These results indicate that the tendency for Economy fuses to deteriorate while carrying their rated current is much greater in the larger sizes than in the smaller, as would be expected because of the greater heat developed, and the deterioration is markedly greater than in the case of fuses using powdered filler with which they were compared. Measure-

ment of temperature of the fiber cartridge of various makes of fuses while carrying their rated current showed that the Economy fuses operate at a considerably higher temperature than the fuses containing powdered filler, and this is no doubt largely responsible for the deterioration observed.

7. *Voltage of Fuse Tests.*—The majority of the foregoing tests were made in accordance with the best conditions specified by the Underwriters' Laboratories. These require that fuses shall be tested singly on the full voltage for which they are rated, whereas in actual practice almost all fuses operate with two in series on short circuit. It is extremely rare in practice that a single fuse is short-circuited, except on Edison three-wire systems, or on 3-wire single-phase circuits, and in such cases only half the voltage is impressed on the one fuse. In this respect, therefore, the test conditions are much more severe than the voltage conditions that would usually prevail in practice, and in the above experiments in which two fuses were blown in series on the rated voltage of the fuses, the operation of Economy fuses was entirely satisfactory, though the limiting current was 10 000 amperes, as called for by the Underwriters' specifications. It is also a fact that the great majority of fuses in service are not called upon to open a severe short circuit, there being usually a considerable amount of resistance in the circuit which makes the operation of the fuse much more certain and reliable.

8. *Possible Short-Circuit Currents in Practice.*—We have made special investigations to determine the probability of obtaining under service conditions short-circuit currents of the magnitude specified by the Underwriters' Laboratories, and these tests show that if the short circuit should occur near the cut-out, currents of 10 000 amperes or greater may very frequently be obtained within a considerable territory near a large modern power plant. In particular, in one large city a considerable number of regulation tests were made at places selected at random in the Edison three-wire district. Calculations from these regulation test data showed that at nearly all points tested the short-circuit currents would exceed 10 000 amperes and in some cases values as high as 90 000 to 100 000 amperes were obtained. It is evident, therefore, that it is possible to obtain in practice short-circuit conditions much more severe than those imposed in the Underwriters' specifications; although such large currents would undoubtedly be very unusual, since short circuits do not as a rule occur at the cut-out.

9. *Effect of Inductance on Fuse Performance.*—Experiments show that even where comparatively small short-circuit currents are used amounting to only a few hundred amperes, if there be a high inductance in the circuit such as might frequently be encountered, the performance of fuses may be expected to be very bad. As a matter of fact it is our understanding that the specifications of the Underwriters are designed not so much to represent actual extreme conditions to which fuses may be subjected in practice, but rather to represent the present state of development of the art of fuse manufacture, it having been shown that it is entirely practicable to meet these requirements without imposing any undue hardship on the fuse manufacturers, although the cost of maintaining this standard has not infrequently been complained of by fuse users.

10. *Comparative Results of Fuse Tests.*—A careful examination of the records of the tests above referred to shows that in general the performance of Economy fuses under the test conditions prescribed by the Underwriters' Laboratories was decidedly inferior to that of the majority of the makes of approved fuses with which they were compared. There was one notable exception, however, there being one make of approved fuse which in the ferrule type proved quite uniformly less satisfactory under test than the Economy fuse, and was but little better than the Economy fuse in most of the knife-blade sizes. The performance of the fuse of this make, however, was decidedly below the limit set by the Underwriters' Laboratories, a condition which may at times develop in any device which has been once approved. When such a condition is found to have developed, however, it is the practice of the Underwriters' Laboratories to demand that the device be brought up to standard on penalty of withdrawing approval if this is not done within a reasonable time. We understand that any new line of fuses performing as these fuses perform would not be approved by the Underwriters' Laboratories, and if such a performance should persist for a considerable time in any approved line of fuses the approval would be withdrawn. Further, the tests show that Economy fuses in service tend to deteriorate more rapidly than fuses using powdered filler, so that the comparison of old fuses would probably be still less favorable to the Economy fuse. This is more important in refillable fuses than in nonrefillable fuses because the former are likely to be kept in the customers' cut-outs for a longer time. It follows, therefore, that if Economy fuses were to to be approved, in view of their performance under these tests, the

result would be a distinct lowering of the standard of fuse performance as shown by short-circuit tests.

The tests described above, however, show quite clearly that it is entirely practicable from a manufacturing standpoint to manufacture fuses that will give very satisfactory performance under the tests imposed by the Underwriters' Laboratories, so that before changing the test requirements so as to lower the standard of fuse performance we should be definitely assured that on the one hand no serious hazard would result from so doing, or that any hazard which might be introduced would be fully justified by compensating advantages. The compensating advantages alleged for the Economy fuse are two in number, namely, (1) that they reduce the cost of fuse maintenance to the user; and (2) that the ease with which they can be refilled by the user will in large measure reduce the tendency to dangerous misuse in comparison with nonrefillable fuses. Data bearing on these questions have been obtained by the Bureau of Standards in its investigations of the use of Economy fuses.

INVESTIGATIONS REGARDING THE USE OF ECONOMY FUSES

1. *Abuse of Approved Fuses.*—The investigations made by the Bureau of Standards regarding the use of both Economy fuses and approved cartridge fuses have established several important facts. The first is that there is in many places a certain amount of abuse of approved fuses. This may take a great variety of forms, many of which make it absolutely impossible for the fuse to perform its proper function, thereby introducing a serious fire or accident hazard either by lack of protection for circuits and apparatus or by danger from the operation of the fuse itself.

The chief form of abuse of approved fuses appears to be the practice of bridging the fuse on the outside with heavy fuse wire, copper, or iron wire, or putting a nail or wire through the center of the fuse cartridge. Occasional forms of abuse met with consist of taking out the filler and pouring the fuse cartridge full of melted solder or placing a bolt through the cartridge. Some of these are extremely difficult to detect on superficial examination. In certain localities the tendency to abuse approved inclosed cartridge fuses, as above indicated, is surprisingly great. On one inspection trip made by one of the engineers of the Bureau of Standards one out of seven of all the approved inclosed fuses examined (379 in all) was found to be improperly refilled. In other inspection trips the tendency to abuse such fuses was found to be relatively small.

The evidence obtained also shows that there is a large amount of refilling of approved fuses by small shops which make this a regular business. The manufacturers advertise that such fuses can be refilled and offer to do it for the users, but this often is not very convenient, it being much easier to have the work done by some local mechanic, especially when a small stock of fuses is carried. When fuses are refilled this way in small shops there is no assurance that they will be properly refilled and we have learned in some cases that they are as badly abused in refilling as when the users refill them themselves with improper fuse links or improper wire.

Subsequent to the formal hearing at Washington the manufacturers of approved fuses presented to the Bureau of Standards a number of samples of Economy fuses taken from service which showed evidences of charring of the fiber cartridge as well as other evidences of defective performance under practical conditions. That this is not peculiar to the Economy fuse, however, is evidenced by the fact that inspectors of the Bureau of Standards have also encountered similar defects in specimens of approved cartridge fuses, although the evidence tends to indicate that the tendency for charring of the cartridges in use is greater in the Economy fuse than in the approved fuses.

2. *Abuse of Economy Fuses.*—The evidence that has been obtained shows quite clearly that there is also some abuse of Economy fuses in service, which abuse may also take a variety of forms, such as refilling with a number of fuse elements, or refilling with copper, aluminum, or other metal strips or wire. The evidence, however, indicates that up to the present time there has been relatively less of this form of abuse in the case of the Economy fuse in proportion to the number used than in the case of standard inclosed fuses, due largely no doubt to the relative ease with which Economy fuses can be refilled with the proper element. It would appear, therefore, that although Economy fuses may themselves introduce certain hazards not occurring with approved fuses, they at the same time tend to reduce one of the chief sources of danger connected with the use of the latter, which in a measure at least compensates for any hazard which may be peculiar to the Economy fuse and possibly is more than a fair equivalent for such hazards.

3. *Experience with Economy Fuses in Practice.*—Experience available up to the present time shows that while there have been

numerous cases where individual Economy fuses have failed in various ways to perform their functions, there is, nevertheless, no evidence available indicating that the fires or accidents resulting from such failures exceed those which would have occurred with approved fuses, so that it can not be contended, except by inference, that the use of Economy fuses up to the present time has actually increased the fire or accident hazard.

The testimony of users of Economy fuses indicates that experience up to the present time has been in the main favorable to the Economy fuse, but this should not be adopted without reserve as indicating the wisdom of approving this type of fuse for general use. There are several reasons for this. First, most of the experience to date has been with a type of fuse which differed in several respects from the type now being sold. One very important change has been the abandonment of the use of powdered filler, the use of which unquestionably gives better performance than is obtained with the present type of unfilled fuse. A second consideration is that the experience available up to the present time is for the most part in connection with installations in which the fuses have been used under the supervision of a competent electrician, and in a large proportion of the cases also the fuses have been used in closed cabinets, which would practically eliminate fire or accident hazards that might otherwise be involved in their use. A third element involves the fact that favorable testimony may often be due to lack of appreciation of what constitutes satisfactory fuse performance. Some users of Economy fuses report to the Bureau of Standards that their experience with these fuses has been very satisfactory, but their statements also show that a considerable number of their fuses exploded the cartridges on blowing. Such fuse performance can of course not be regarded as satisfactory under the standards laid down by the Underwriters' Laboratories, nor from general considerations of safety. It is evident, therefore, that the mere statement by a user that his experienee with Economy fuses has been satisfactory should not be given too much weight until all the details of the fuse performance in his installation have been determined.

CONCLUSION

It appears from the foregoing résumé of the Bureau's investigation that the Economy fuse, when new and properly filled or refilled, operates satisfactorily under the most common working

conditions of overload and moderate short circuits when in circuits with low inductance, and possesses some marked advantages over the approved fuses with which it has been compared. This fuse is, however, distinctly inferior to most of these approved fuses under severe short-circuit conditions. It has not yet been established that it will not introduce hazards peculiar to refillable fuses, owing to deterioration from repeated blowing of the fuse elements in the same casing and possibly from long-continued subjection of the fuse to the working current. The approval of the present type of Economy fuse for unrestricted use would therefore result in a lowering of the standard of fuse performance under severe test conditions and might introduce hazards in actual use the importance of which it is difficult to estimate at this time. The experience with the present type has not yet been sufficient to determine whether the total hazard is greater or less than it is with approved fuses as they are actually used in practice. The investigation therefore leads to the following finding.

FINDING

1. It has not been shown that the use of the fuses manufactured by the Economy Fuse & Manufacturing Co. will result in no greater fire or accident hazard than the use of inclosed cartridge fuses at present listed as standard by the Underwriters' Laboratories (Inc.).

2. On the other hand, the evidence in the case does not show that the use of Economy fuses has, on the whole, resulted in any greater fire or accident hazard than is involved in the use of standard inclosed cartridge fuses.

3. In comparison with fuses listed as standard by Underwriters' Laboratories, the fuses at present manufactured by the Economy Fuse & Manufacturing Co. have been shown to possess certain features which tend to increase the hazards involved in the use of fuses, and other features which tend to reduce such hazard. The relative importance of these features can be determined only by extended experience under working conditions.

4. It is therefore recommended that Economy fuses be not approved at present for general use on the same basis as fuses at present listed as standard by Underwriters' Laboratories (Inc.), but that a continuation and extension of their use be permitted by municipal and underwriters' inspection departments under conditions where their performance can be observed by each

inspection department until sufficient experience regarding their performance under service conditions can be obtained to justify an unqualified approval or refusal to approve.

The evidence on which the foregoing decision has been reached is summarized and discussed in the succeeding sections of this report.

II. EVIDENCE SUBMITTED BY THE ECONOMY FUSE & MANUFACTURING CO. IN ADVANCE OF THE HEARING

CHARACTER OF PRELIMINARY EVIDENCE

The evidence submitted by the Economy Fuse & Manufacturing Co. prior to the hearing held in Washington on July 8 consisted in large part of opinions of users of fuses and of inspectors who have had considerable knowledge of the use of Economy fuses. The opinions of users of fuses were obtained chiefly through the medium of circular letters sent out by the Economy Fuse & Manufacturing Co. requesting answers to stated questions. The opinions of inspectors were in the form of letters and affidavits setting forth the extent and character of the experience the authors had had with Economy fuses. There were also submitted by the Economy Fuse & Manufacturing Co. samples of various makes of approved fuses for the purpose of demonstrating the ease with which such fuses could be refilled by the user, notwithstanding the fact that they are not intended to be so used.

After this evidence had been examined by the engineers of the Bureau of Standards, inspectors were sent to a considerable number of premises represented in the reports for the purpose of securing any additional evidence that might not have been called forth by the questions submitted and also for the purpose of determining upon a satisfactory basis for judging the significance of the testimony contained in the statements of the users. The results of these inspections are set forth and discussed in some detail in a later section of this report.

The significance of the evidence above mentioned was interpreted at some length by representatives of the Economy Fuse & Manufacturing Co. at the formal hearing on July 8, the record of which is given below:

PRELIMINARY STATEMENT MADE BY THE ECONOMY FUSE & MANUFACTURING CO.

OUTLINE OF EVIDENCE

I

The question submitted for determination is one of fact. It is—

Has it been *shown* that the *use* of the fuses manufactured by the Economy Fuse & Manufacturing Co. results in no greater fire or accident hazard than the use of other cartridge-inclosed fuses at present approved by the Underwriters' Laboratories (Inc.)?

The "other" fuses are the following:

"Buss".....Bussman Manufacturing Co., St. Louis. (Sample No. 1.)
"G. E.".....General Electric Co., Schenectady, N. Y. (Sample No. 2.)
"Union".....Chicago Fuse Co., Chicago, Ill. (Sample No. 3.)
"Arkless".....Detroit Fuse Co., Detroit, Mich. (Sample No. 4.)
"Shawmut".....Chase Shawmut Co., Newburyport, Mass. (Sample No. 5.)
"Killark".....Killark Electric Manufacturing Co., St. Louis, Mo. (Sample No. 6.)
"Noark".....Johns Pratt Co., Hartford, Conn. (Sample No. 7.)
"Bryant".....Bryant Electric Co., Bridgeport, Conn. (Sample No. 8.)
"D. & W.".....D. & W. Fuse Co., Providence, R. I. (Sample No. 9.)
"K. E.".....Kirkman Engineering Co., New York City.
"Metropolitan".....Metropolitan Engineering Co., Brooklyn, N. Y.
"Multi".....Multi Refillable Fuse Co., Chicago, Ill. (Sample No. 10.)
"United".....United Electric Supply Co., Brooklyn, N. Y.
"Westinghouse".....Westinghouse Electric & Manufacturing Co., Pittsburgh, Pa.

Where no sample is referred to the fuses are used so little that samples are not readily obtainable.

Each of the foregoing fuses is approved by the Underwriters' Laboratories (Inc.), and the question is whether the use of Economy fuses results in no greater fire or accident hazard than the use of any one of those named above, not some or a favored one or two, because the question is whether the Economy fuse is being discriminated against on the question of the relative fire hazard involved in the use of the devices.

II

This question arises because, as will be found on reading the communication of the Economy Fuse & Manufacturing Co. of April 2, 1915, to the Underwriters' Laboratories (found on p. 133 of printed appeal to N. F. P. A.), it was shown that many of the approved fuses named above are so designed and constructed as to permit the ready replacement of the fusible element (especially in the knife-blade types) and the reassembly of the fuse without injury to any of the parts by the user, which results in a positive invitation to the user to refill, irrespective of the so-called announced intent of design, especially as many of the fuses bear a printed label that the fuse will be refilled by the maker, and one company calls itself "Multi Refillable Fuse Co."

The samples of the fuses mentioned above are submitted to the Bureau to show from simple inspection how easily they can be renewed.

It is not claimed that these approved fuses as renewed by the maker are tested for safety of operation, and an inspection alone of the fuses shows that they are not so ruggedly constructed as to stand repeated renewal, even when skillfully done.

It is also apparent from inspection that the omission of the filling material on reassembly would be dangerous because of the open ventholes and very thin caps.

III

EXTENT OF USE OF ECONOMY CARTRIDGE-INCLOSED FUSES

The company has 7080 direct customers. (A full alphabetical list for reference as to character of users is found in volume 14 of the record submitted to the Bureau of Standards.)

The diversity of the use will be found from an inspection of this list. The Economy fuses are in daily use in all States in the Union, and throughout Canada, some in Russia, Germany, France, and England, and in Argentina, South America.

The character of the users will also be found to embrace every kind of industrial installation, large and small; steamships and railroads.

The Economy fuses have been in service for three years. The extent of the use is evidenced by the following numbers of Economy fuses in actual service:

377 993 ferrule type, 250 volts, 3–60 amperes, with filler.
55 050 ferrule type, 600 volts, 3–60 amperes, with filler.
433 470 ferrule type, 250 volts, 3–60 amperes, without filler.
60 494 ferrule type, 600 volts, 3–60 amperes, without filler.
51 842 knife-blade type, 250 volts, 61–600 amperes, with filler.
9240 knife-blade type, 600 volts, 61–600 amperes, with filler.
24 484 knife-blade type, 250 volts, 61–600 amperes, with asbestos sheath.
5405 knife-blade type, 600 volts, 61–600 amperes, with asbestos sheath.
119 887 knife-blade type, 250 volts, 61–600 amperes, free drop-out link.
10 165 knife-blade type, 600 volts, 61–600 amperes, free drop-out link.

Total fuses ferrule type	940 514
Total fuses knife-blade type	221 023
Total	1 161 537

Frequency of operation is shown by the sale of renewal links, divided as follows:

Ferrule type links, 3–60 amperes	1 606 204
Knife-blade type links, 61–600 amperes	425 596
Links given with fuses	1 601 117
Total links	3 632 917

Fuses of older types with filling material or with asbestos sheathing over link are rapidly disappearing, and are replaced with latest type free drop-out link fuses wherever users will consent.

IV

Comparative cost of fuses, cheapness of Economy renewal elements, and ease of refilling and reassembly.

The example taken is the most extensively used size 100-ampere knife-blade type, 250 volts; other comparisons will be in the same ratio.

	Cents
The average cost of present standard nonrefillable fuses, new	40
Recently announced to be reduced on account of agitation by this company to	24
Cost of refilling by maker (expressage and packing paid by user)	16
Cost of Economy fuse shell with 2 links free	90
Or initial cost per link	30
Renewal links	5
Economy fuses have been renewed on severe short-circuit test 50 times with perfect operation, and in some instances in practice 75 times. On an average of 10 renewals, which no "approved fuse" will stand, the cost per fuse to the user is	13
If renewed 20 times, the cost is	9

	Cents
Ten "Approved fuse" blow-outs, with the utmost refilling by the maker which the fuse shell and parts will stand, which we put for liberality at 3, would be at the proposed reduced rates	19
If refilled by the maker once, the cost, not including packing, shipping, etc., would be	20

V

Extent of use and relative cost are important factors. Such widespread use by such important, carefully conducted industries could not be possible in the face of the enormous opposition the company has encountered from certain insurance organizations of nation-wide activity, and from competitors who have left no stone unturned to stop the growth of the company's business, if, as it is alleged by some, the Economy fuse was a fire hazard and a dangerous device, and their use takes the answer to the question submitted out of the realm of the imagination and opinion and reduces it to an easily ascertained fact.

The comparison of cost shows the reason for the constantly recurring statement that the high cost of renewals is one of the chief causes of the dangerous practice of refilling so-called nonrenewable fuses, and that the cheapness of Economy renewal links (as cheap as one-fourth cent in the small sizes) and ease of insertion are what tend to reduce or eliminate this dangerous practice.

The making and selling of cartridge-inclosed fuses has been a large, profitable business, controlled for years by a few strongly intrenched companies, practically all operating under licenses from one patent owner. It is, to those who know the real facts of the fuse situation, not surprising that the entrance into this supposedly well-walled field of a device for which there has long been a crying need, and one which was designed to overcome the very evils long recognized as flowing from the use of the then known devices, should provoke a storm of criticism and engender opposition from every possible quarter from which it could be made to come.

The imagination has been racked and opinions based thereon emphatically stated as facts, often innocently, often intentionally, to injure the Economy fuses until if the Economy fuses from actual experience with their use secured under the most exacting conditions of watched use by insurance inspectors had not completely demonstrated the fallacy of all the imaginings and expert opinion based thereon and proved that they do correct the evils attendant on the use of approved fuses to at least some extent, the Economy Fuse & Manufacturing Co. would have ceased to exist long ago.

Therefore, we say the answer to the question submitted is not to be determined by the announcement of opinion, expert or otherwise, no matter how vehement, when not based on the facts of experience.

It is these facts of the experience of users of the fuses and of insurance inspectors who have carefully watched their use, with the preconceived notion that they were dangerous, which must determine the question and which are submitted herewith.

Before setting forth the facts it should be borne in mind that there is a vast amount of real ignorance existing in regard to the dangerous operation of fuses when new, and the causes therefor, and that much faulty fuse operation is due to defective cut-out blocks and unknown circuit conditions, which sometimes results in the use of a certain type of fuse under conditions it was not constructed to meet.

VI

The evidence of the use of Economy fuses shows that in practice they are refilled properly and operate safely and reduce or eliminate to a large extent the tendency to improperly overfuse circuits because of cost of renewals, lack of sufficient stock, or inaccessibility to stocks, which are admittedly by far the most frequent causes of dangerous overfusing.

It is not contended that the use of Economy fuses will prevent intentional overfusing where a specific reason for such overfusing exists and a desired object is sought, but in such cases experience shows this is true of any fuse because a fuse in such cases is not wanted, but a continuous circuit, and even then the overfusing of Economy fuses is safer than the usual practice of bridging terminals.

It is shown, however, that many cases of intentional overfusing with nonrefillable types are done away with because of the quickness, ease, and cheapness of renewing where there are frequent blow-outs on crowded machinery where delays are a greater damage than the fire likely to result.

The evidence was secured from about 1000 users of fuses and from the principal inspection departments of fire boards in the larger cities.

The evidence of the users is for convenience bound in volumes, the method of division being largely with a view to grouping those who admit refilling of nonrefillable fuses at the plants, and those who deny such practice, those who make general statements on the experience with the use of the fuses, those who use only a very few fuses, and so on, as is shown in the following digest of what in general is contained in each of the 15 volumes of evidence submitted.

Volume I (X)

These statements of 105 users of Economy fuses are specially grouped because all are from industrial installations insured in what are known as factory mutuals, and are interesting because the inspection department of these companies has been most bitterly opposed to the use of Economy fuses and has ordered them out wherever found, and their risks would stand for the arbitrary action. This department has been most insistent that the refilling of approved nonrefillable fuses in their risks does not exist, and is carefully watched by their inspectors.

Yet, of 101 answering the question, 41 state that they do refill on the premises. This is 40 per cent in carefully watched plants. Eighty-eight of these users stated that the Economy fuse has been at all times satisfactory. Ten state they have not used the fuse and 3 state the use has not been satisfactory, 4 not answering. Eighty-one state that the fuses have at all times been properly refilled, many making very full statements showing the satisfactory operation, proper renewal, and reduction of fire hazard by the now proper fusing of circuits. Twenty-one do not answer the question and 3 state the fuses have not at all times been properly refilled. These are Nos. 3, 49, and 70.

Volume II (A)

This volume contains the statements of 88 users of Economy fuses, 44 of whom admit that they refilled approved nonrefillable fuses, and many of whom give lengthy dissertations on their experience in the use of both kinds of fuses and the protection resulting from the use of Economy fuses.

Volume III (B)

This volume contains the statements of 54 users of fuses, 36 of whom admit the refilling of approved so-called nonrefillable fuses on their premises, but only a few of whom give detailed statements on the general situation.

Volume IV (C)

This volume contains the statements of 108 users, each of whom deny that they refill approved nonrefillable fuses, many of whom give detailed statements of their satisfactory experience with the use of Economy fuses.

VOLUME V (D)

This volume contains statements of 82 users, 74 of whom admit that they refill approved nonrefillable fuses and each of whom give detailed statements concerning the reduction of the fire hazard resulting from the use of Economy fuses and the greater protection afforded against overfusing circuits.

VOLUME VI (E)

This volume contains 45 statements from users who neither affirm nor deny that they refill approved nonrefillable fuses, but give their satisfactory experience with the use of Economy fuses.

VOLUME VII (F)

This volume contains the statements of 132 users of fuses grouped together because their consumption of fuses is very limited.

VOLUME VIII (G)

This volume contains the statements of 35 users who did not wish to answer the specific questions asked, but make a general report on their use of the Economy fuses and the reduction of the fire hazard from their use.

VOLUME IX (H)

This volume contains 184 letters from users who did not wish to make replies on the printed form submitted.

VOLUME X (I)

This volume contains 57 letters in addition to those in Volume IX.

VOLUME XI (K)

Eight letters separated because from factory mutual risks.

VOLUME XII (J)

Seventeen miscellaneous statements received too late to classify as above.

VOLUME XIII

In this volume will be found transcribed for easy reading all the statements made by the users in the foregoing volumes and which bear on their experience in the use of Economy fuses as reducing or eliminating the practice of overfusing circuits by refilling approved nonrefillable fuses. These excerpts are all key numbered to the volumes named above so that the original may be examined for verification.

VOLUME XIV

This volume contains:

1. An alphabetical list of all direct customers of the company.
2. An alphabetical list of all concerns giving statements with their location and name and official position of the party testifying, each of which is keyed to the volumes above mentioned.

VOLUME XV

This volume contains the very important testimony by way of affidavits of insurance and municipal inspection departments having wide jurisdiction covering the jurisdictions where fuses are most extensively used.

There is also in this volume the letters of authority for the use of Economy fuses granted by various inspection departments.

ECONOMY FUSE & MANUFACTURING CO.,
R. J. FOOTE, *Director*.

SUMMARY OF INFORMATION CONTAINED IN TESTIMONY OF USERS OF ECONOMY FUSES

The answers to the questions sent out to the users of Economy fuses by the Economy Fuse & Manufacturing Co. covered a wide range of subjects, and many of the answers have no direct bearing on the question under consideration. There is presented below a brief digest and summary of the answers to those questions which are judged to be relevant to the question at issue.

1. *Scope of Answers Received.*—Altogether about 1,000 users of Economy fuses were asked to submit statements, but as a rule less than half of these answered any particular question submitted. Of those answering the great majority reported that their experience with Economy fuses had been entirely satisfactory. A total of 28 users, however, stated that their experience had not been satisfactory, though in many cases no specific statement was made indicating the objections which the company had to the use of Economy fuses. The significance of this statement may perhaps best be gauged if we consider that 55 of these same users reported unsatisfactory experience with fuses in general, including approved types. It appears also from the records that the fuses are, in general, being used in places where frequent renewals are necessary. This of course is to be expected, because it is in such places that the refillable fuse offers the greatest advantage, and it is also a condition tending to give a maximum of experience with such fuses within any limited time.

2. *Percentage of Replacements.*—In answer to the question as to what percentage of all fuses were replaced per annum only 300 replies were received. Of these about 40 per cent stated that the annual renewals amounted to less than 25 per cent; 22 per cent indicated that annual renewals amounted to between 25 and 50 per cent, and 10 per cent that renewals amounted to more than 100 per cent. The average of all percentages reported indicated about 62 per cent of renewals per annum, about two-thirds of which were on motor circuits. By far the greater portion of all renewals was shown to have been made necessary by the overloading of motors due to workmen forcing the machinery or work.

The percentage of replacements due to poor contact in either fuse clips or adjacent switches is indicated by replies from 210 users. Of these 146 reported that less than 25 per cent of their fuses were blown from this cause; 15 reported that between 25 and 50 per cent of their fuses were blown because of bad con-

tacts; and individual users reported a still higher percentage. There is nothing in the testimony indicating the relative probability of fuse failures due to this cause in the case of approved nonrefillable fuses, but the engineers of the Bureau of Standards have frequently had occasion to note that the contacts of the knife blades in the cut-out clips were very often less perfect in the case of Economy fuses than of approved fuses, particularly in fuses that had been refilled, this being due to lack of care in aligning the knife blades when refilling the fuse. No evidence has been presented, however, indicating that any actual hazard has resulted from this cause.

3. *Failure of Indicators.*—The evidence brought out in the letters seems to reveal considerable trouble on the part of users with the operation of indicators on approved fuses. Of 389 users reporting on this point only 38 reported that their experience with indicators had been satisfactory, 351 users reporting adversely. The trouble results both from a failure of the indicator to operate and show when the fuse has been blown and also in many cases from the operation of the indicator without the fuse having blown. This latter trouble might be construed to involve an appreciable hazard because of the possible careless handling of electrical circuits that are erroneously supposed to have been opened by the fuse. A number of companies reported that a considerable portion of their indicators fail without any actual operation of the fuse. The great majority of the users reporting appear to take the view that an indicator is not an essential part of the fuse, and many do not rely on the indicators provided in standard fuses but use some method of direct testing to determine whether or not the fuse has blown.

4. *Returning of Approved Fuses to Manufacturer for Refilling.*—The answers indicate that a comparatively small portion of these users have followed the practice of returning approved nonrefillable fuses to the manufacturers for refilling. Of 451 reporting on this question 68 answered in the affirmative and 383 in the negative. The majority of those reporting expressed the opinion that approved fuses refilled by the manufacturer gave as good service as when new, but 64 did not concur in this view; 127 reported that the saving on fuses refilled by the manufacturer was not sufficient to justify the increased investment for spare fuse cartridges and the trouble of handling the order and expense incident to shipment.

5. *Refilling of Approved Fuses by Parties Other than Manufacturer or User.*—The practice of having approved nonrefillable fuses refilled at places other than the maker's factory or on the user's premises was indicated to be quite prevalent. Of 321 companies reporting on this practice 45 reported that they were having approved fuses refilled in this way. The testimony indicates, however, that the majority of these have not found such refilling as satisfactory as that done by the original maker.

6. *Refilling of Approved Fuses by the User.*—The testimony submitted by these users of fuses indicates a surprising tendency to refill approved nonrefillable fuses on the user's premises. Out of 435 users answering this question 187, or about 43 per cent, stated that they followed this practice, while 57 per cent reported that they did not refill fuses in this way. Of those companies reporting that they did refill approved fuses on their own premises the majority reported that it was their custom to use lead fuse wire or strip, although a considerable number used aluminum, zinc, or copper. It has been quite definitely established that the performance of fuses filled with lead, aluminum, or copper is in general distinctly inferior to their performance when filled with zinc elements; so that the practice here indicated of refilling standard fuses with improper materials must be regarded as increasing the hazards that might be involved in the use of such fuses. It is true that these same users not infrequently refill their Economy fuses with improper material, as shown by the answers, but this tendency was much less marked than in the case of the approved fuses. For example, 161 companies reported that they refilled approved fuses with lead wire or strip; whereas only 17 companies reported refilling Economy fuses in this way; 24 companies reported refilling approved fuses with copper wire or strip, while only 7 companies refilled Economy fuses in this way.

7. *Saving Due to the Use of Refillable Fuses.*—The great majority of users reporting expressed the view that the use of Economy fuses would materially reduce the cost of fuse maintenance, although a total of 22 companies answered this question in the negative. The majority of the users reported that the reduction in cost of fuse maintenance due to the use of Economy fuses ranged from 25 to 100 per cent, and 7 companies reported a saving in excess of 100 per cent. This latter indicates that the question was in some cases misunderstood, so that there may be some question as to the accuracy of the figures given. The

average saving as indicated by the answers was about 81 per cent.

8. *Criticisms of Economy Fuses by Those Who Use Them.*— Many criticisms are based on experience with the earliest type of cartridge fuse put out by the Economy Fuse & Manufacturing Co. and do not hold for the more recent types. In this earliest type the fuse strip was clamped between a washer and a ferrule screwed onto a fiber tube. The criticisms indicate that this method of clamping the fuse strip is unsatisfactory. Moisture, vibration, and shrinkage of the fiber loosened the ferrule and caused a high resistance contact between the fuse link and the ferrule, which frequently charred the fiber, due to overheating, destroying the threads on it. This trouble is obviated in a later type of fuse in which the electrical circuit is independent of the fiber tube and loose contact between the ferrule and fiber does not affect the operation of the fuse. There are a few reports of fuse strips being too long. As a result of the excess length of the fuse strip the ends of the strip catch in the threads of the clamping ferrule of the ferrule type and prevent a good contact between ferrule and fuse. In the knife-blade type the knife blades are sometimes thrown out of alignment, which may cause poor contact in the cut-out.

A third type of criticism applies to the marking of the fuses. The paper labels are said by some to come off, and others report that the rating of the refill strip is not marked in large enough figures. The trouble on this account might cause some inconvenience but could scarcely be called a hazard.

There are a few criticisms that the fuse strips break when they are bent over the washer in refilling. This trouble will add to the expense of using the fuse, but should cause no danger since the break is apparent before the fuse is replaced in circuit.

One reply says that the 600-volt fuses hold the arc when the fuse strips are not uniform or double notched. One other reply reports a single case of arcing which destroyed the fuse block. A few companies state that the Economy fuses will not carry as much current as approved fuses of the same rating.

The two criticisms of a serious nature are poor contacts due to too long fuse strips, and holding the arc. The first of these is apparently due in most cases to shrinking of the fiber, due to long-continued heating in normal use. The most serious criticism, that of holding an arc, is offered by but two observers, only one

of whom, an operator of a street railway, reports more than a single instance.

9. *Attitude of Users Toward Refillable Fuses.*—The fuse users reporting were all but unanimous in expressing the opinion that a suitably designed refillable fuse which met all the Underwriters' performance specifications should be approved. Out of 418 replies bearing on this point only 8 indicated that such a fuse should not be approved.

10. *Character of Users Represented in Statements.*—That the users whose opinions are here considered represent fair average conditions as regards character of their power supply system is indicated by the testimony. Of 269 specific answers, 172 stated that they used central station service, while 97 stated that their supply was from isolated plants. The capacity of the plants was said to range from a minimum of 1 kilowatt to a maximum of 100 000 kilowatts, the average capacity of all the plants reported on being 4800 kilowatts. There was a similar wide variation in size of feeders, a minimum of 26 000 circular mils being indicated and a maximum of 3 000 000 circular mils. The users of alternating and direct current were about equally divided, and about 25 per cent of the users reporting used both classes of service. The voltages of the circuits reported were 110, 220, 440, and 600 volts, but the great majority used 220-volt service.

11. *Summary of Statements of Users.*—The general trend of the testimony reviewed above appears to be decidedly favorable to the Economy fuse, although even among habitual users of these fuses experience has not been altogether satisfactory. It should be borne in mind, however, that this testimony can not be accepted without reserve as representing the experience or opinions of all users of fuses. The mere fact that these companies are using Economy fuses is sufficient to place them in a select class which might very naturally be expected to express favorable opinions regarding the use of these fuses. Before these opinions can be accepted as reflecting the general trend of opinion among fuse users it is necessary to take into account the possibility that a great many users may have at one time or another considered the use of Economy fuses but refrained from ever using them for reasons which they deemed sufficient but which it would be extremely difficult to get into the record of the present case.

Furthermore, firms using unapproved fuses in insured properties would very naturally be reluctant to give any evidence tending to show that they were continuously incurring an appreciable

hazard even though events may have transpired which would lead the user to suspect a possible increase in hazard. We must therefore deal with the possibility that in certain cases the statements may not accurately reflect the opinion of the users themselves.

EXHIBITS OF IMPROVED FUSES SUBMITTED BY ECONOMY FUSE & MANUFACTURING CO.

The specimens of approved fuses submitted to the Bureau show quite clearly that such fuses can readily be refilled by the users and that such refilling is actually done to a considerable extent has been clearly shown by investigations made by inspectors of the Bureau of Standards which are discussed in a later section of this report.

STATEMENTS FROM INSPECTORS

Letters from inspection departments and affidavits from inspectors presented by the Economy Fuse & Manufacturing Co. are all very favorable to the use of Economy fuses, and on their face would appear to convey beyond question the idea that the authors of the statements are convinced that not only have Economy fuses proved satisfactory in use, but that there is no reason why they should not be formally approved by the Underwriters. These letters and affidavits are discussed in a later chapter of this report dealing with the formal hearing at the Bureau of Standards on July 8, so that they will not be taken up in detail here.

III. PRELIMINARY EVIDENCE SUBMITTED BY THE UNDERWRITERS' LABORATORIES

The preliminary evidence submitted by the Underwriters' Laboratories consisted of reports of comparative tests made on Economy fuses and various makes of approved fuses, and also of the results of short-circuit tests of Economy fuses.

RATING TESTS

The reports on the rating tests gave data on tests of a number of makes of approved fuses as well as of Economy and other fuses not approved, of various sizes, the loading varying from 110 per cent to 150 per cent of the rated current of the fuse. The data obtained included the time required for blowing the fuses under the different current values used, and also the maximum temperature rise of the fuse cartridge. The results of these tests are shown in Table 1, which is practically self-explanatory. In the

column headed "maker" the letters refer to the key given at the end of the table. The results of these rating tests show in general a very satisfactory performance of Economy fuses.

An examination of Table 1 shows that Economy fuses met the requirements of the National Electrical Code Rule 68, Sections H and J. It will be noted that the time required for blowing the fuse on 50 per cent overload is in most cases shorter than that required by the other fuses with which the Economy fuse was compared. On 10 per cent overload the maximum temperature reached is higher than for most of the other fuses, but within the limits permitted by paragraph 1, Rule 68 of the Code, with the exception of the 100-ampere 250-volt fuses tested in August, 1914, which came within the limit on rated current.

TABLE 1

Comparison of Economy and "Approved" Fuses Tested by Underwriters' Laboratories (Inc.)

250-VOLT FUSES

Elec. No.	Date	Number tested	Rating	Load, per cent rating	Maker [a]	Maximum time to open circuit	Maximum temperature rise before blowing
			Amp.				°F
3408	May 20, 1914	10	10	150	E	Blown 4 sec	
3542	Mar. 3, 1913	3	10	150	U	Blown 20 sec	
3542	Dec. 28, 1914	6	10	150	U	Blown 3 sec	
3578	Sept. 25, 1914	6	10	150	S	Blown 5 sec	
3654	Sept. 8, 1914	6	10	150	K	Blown 15 sec	
4164	Dec. 2, 1914	8	10	150	M R	Blown 32.2 sec	
3716	June 1, 1915	6	10	150	E F	Blown 9 sec	
4273	Jan. 29, 1915	4	10	150	B	Blown 4 sec	
3408	May 20, 1914	4	10	125	E	Blown 1 min. 58 sec	
3654	Sept. 8, 1914	6	10	125	K	Blown 1 hr. 22 min	
3578	Sept. 25, 1914	6	10	125	S	Blown 2 hr. 10 min	
3542	Mar. 3, 1913	3	10	125	U	Blown 55 sec	
3542	Dec. 28, 1914	3	10	125	U	Blown 14 min	
4164	Dec. 2, 1914	4	10	125	M R		112
3716	June 1, 1915	6	10	125	E F	Blown 13 min	112
3408	May 20, 1914	4	10	110	E	Not blown 1 hr. 7 min	52
3542	Mar. 3, 1913	3	10	110	U	Not blown 1 hr. 30 min	34
3542	Dec. 28, 1914	6	10	110	U	Not blown 2 hr	75
3654	Sept. 8, 1914	6	10	110	K	do	45
3578	Sept. 25, 1914	6	10	110	S	Not blown 2 hr. 45 min	39
4164	Dec. 2, 1914	4	10	110	M R	Not blown	112
3716	June 1, 1915	6	10	110	E F	Not blown 1 hr	45
3408	Sept. 18, 1912	6	15	150	E	Blown 45.6 sec	
3542	Mar. 3, 1913	3	15	150	U	Blown 15 sec	
3542	Dec. 28, 1914	6	15	150	U	Blown 10 sec	
3654	Sept. 6, 1914	6	15	150	K	Blown 11 sec	
3408	Sept. 18, 1912	4	15	110	E	Not blown 1 hr	97
3542	Mar. 3, 1913	3	15	110	U	Not blown 2 hr	89
3542	Dec. 28, 1914	6	15	110	U	do	88
3654	Sept. 18, 1914	6	15	110	K	do	63
3578	Sept. 25, 1914	6	15	110	S	Not blown 2 hr. 15 min	56
3716	June 1, 1915	6	15	110	E F	Not blown 1 hr. 15 min	55
3408	Sept. 18, 1912	4	25	150	E	Blown 7 sec	
3654	Sept. 8, 1914	6	25	150	K	Blown 10 sec	
[b] 4199	Mar. 1, 1915	4	25	150	N	Blown 27 sec	

[a] Maker: B=Bussman Manufacturing Co., St. Louis, Mo.; E=Economy Fuse & Manufacturing Co., Chicago, Ill.; E F=Electric Fuseguard Co., Providence, R. I.; K=Kirkman Engineering Co., New York, N. Y.; M=Metropolitan Engineering Co., Brooklyn, N. Y.; M R=Multi Refillable Fuse Co., Chicago, Ill.; N=National Refillable Fuse Co., Chicago, Ill.; S=Star Fuse Co., New York, N. Y.; U=United Electric Supply Co., Brooklyn, N. Y.

[b] Not standard.

TABLE 1—Continued

Comparison of Economy and "Approved" Fuses Tested by Underwriters' Laboratories (Inc.)—Continued

250-VOLT FUSES—Continued

Elec. No.	Date	Number tested	Rating	Load, per cent rating	Maker	Maximum time to open circuit	Maximum temperature rise before blowing
			Amp.				°F
3408	May 20, 1914	4	25	125	E	Blown 4 min.	
3654	Sept. 8, 1914	6	25	125	K	Blown 13 min.	
[a] 4199	Mar. 1, 1915	4	25	125	N		
3408	May 20, 1914	4	25	110	E	Not blown in 1 hr.	110
3654	Sept. 8, 1914	6	25	110	K	Not blown 2 hr. 10 min.	102
[a] 4199	Mar. 1, 1915	4	25	110	N	Not blown	168
3408	Sept. 18, 1912	6	30	150	E	Blown 60 sec.	
3408	May 20, 1914	4	30	150	E	Blown 12 sec.	
3654	Sept. 8, 1914	6	30	150	K	Blown 10 sec.	
4164	Dec. 2, 1914	13	30	150	M R	Blown 76.6 sec.	
3542	Dec. 28, 1914	6	30	150	U	Blown 50 sec.	
4273	Jan. 29, 1915	6	30	150	B	Blown 2 min. 5 sec.	
3716	June 1, 1915	6	30	150	E F	Blown 55 sec.	
3542	Mar. 3, 1913	3	30	150	U	Blown 16 sec.	
3408	May 20, 1914	4	30	125	E	Blown 4 min. 12 sec.	
3654	Sept. 8, 1914	6	30	125	K	Blown 45 min.	
4164	Dec. 2, 1914	3	30	125	M R		
3542	Dec. 28, 1914	6	30	125	U	Blown 32 min.	
4273	Jan. 29, 1915	3	30	125	B		
3542	Mar. 3, 1913	3	30	125	U	Blown 2 min. 20 sec.	101
3716	June 1, 1915	6	30	125	E F	Blown 6 min.	70
3408	Sept. 18, 1912	4	30	110	E	Not blown in 1 hr.	
3408	May 20, 1914	4	30	110	E	do	96
3654	Sept. 8, 1914	6	30	110	K	Not blown 2 hr.	120
4164	Dec. 2, 1914	3	30	110	M R	Not blown	158
3542	Dec. 28, 1914	6	30	110	U	Not blown 2 hr.	120
3542	Mar. 3, 1913	3	30	110	U	Not blown	80
3716	June 1, 1915	6	30	110	E F	Not blown 1.5 hr.	74
3408	Sept. 8, 1914	4	30	100	E	Not blown 1 hr.	119
3408	May 20, 1912	8	35	150	E	Blown 17 sec.	
4273	June 29, 1915	4	35	150	B	Blown 44 sec.	
3654	Feb. 24, 1915	6	35	150	K	Blown 33 sec.	
3408	May 20, 1912	4	35	125	E	Blown 7 min. 19 sec.	
3654	Feb. 24, 1915	6	35	125	K	Blown 28 min.	
3408	May 20, 1912	4	35	110	E	Not blown 1 hr. 7 min.	64
3654	Feb. 24, 1915	6	35	110	K	Not blown 2 hr.	90
3408	Sept. 18, 1912	6	45	150	E	Blown 18.8 sec.	
3542	Mar. 3, 1913	3	45	150	U	Blown 45 sec.	
3578	Sept. 25, 1914	6	45	150	S	Blown 31 sec.	
4164	Dec. 2, 1914	4	45	150	M R	Blown 1 min. 18 sec.	
3654	Feb. 24, 1915	6	45	150	K	Blown 1 min. 2 sec.	
3716	June 1, 1915	6	45	150	E F	Blown 50 sec.	
3408	Sept. 18, 1912	4	45	110	E	Not blown 1 hr.	112
3742	Mar. 3, 1913	3	45	110	U	Not blown 1 hr. 15 min.	104
3578	Sept. 25, 1914	6	45	110	S	Not blown 2 hr.	85
3654	Feb. 24, 1915	6	45	110	K	do	90
3716	June 1, 1915	6	45	110	E F	do	87
3542	Dec. 28, 1914	6	45	110	U	do	93
3408	May 20, 1914	4	55	150	E	Blown 30 sec.	
3654	Feb. 24, 1915	6	55	150	K	Blown 1 min. 19 sec.	
3408	May 20, 1914	4	55	125	E	Blown 7 min. 19 sec.	
3654	Feb. 24, 1915	6	55	125	K	Blown 35 min.	
3408	May 20, 1914	4	55	110	E	Not blown 1 hr.	122
3654	Feb. 24, 1915	6	55	110	K	Not blown 2 hr.	104
3408	Sept. 18, 1912	6	60	150	E	Blown 28.8 sec.	
3408	May 20, 1914	4	60	150	E	Blown 45 sec.	
3542	Mar. 3, 1913	3	60	150	U	Blown 35 sec.	
3578	Sept. 25, 1914	6	60	150	S	Blown 26 sec.	
4164	Dec. 2, 1914	4	60	150	M R	Blown 2 min. 2 sec.	
3542	Dec. 28, 1914	7	60	150	U	Blown 3 min.	
4273	Jan. 29, 1915	4	60	150	B	Blown 1 min. 29 sec.	
3654	Feb. 24, 1915	6	60	150	K	Blown 2 min.	
3716	June 1, 1915	6	60	150	E F	Blown 1 min. 4 sec.	

[a] Not standard.

TABLE 1—Continued

Comparison of Economy and "Approved" Fuses Tested by Underwriters' Laboratories (Inc.)—Continued

250-VOLT FUSES—Continued

Elec. No.	Date	Number tested	Rating	Load, per cent rating	Maker	Maximum time to open circuit	Maximum temperature rise before blowing
			Amp.				°F
3408	May 20, 1914	4	60	125	E	Blown 16 min	
3542	Mar. 3, 1913	3	60	125	U	Blown 7 min. 10 sec	136
3578	Sept. 25, 1914	6	60	125	S	Blown 1 hr	
3542	Dec. 28, 1914	6	60	125	U	Blown 22 min	
3654	Feb. 24, 1915	6	60	125	K	Blown 1 hr. 20 min	
3716	Feb. 1, 1915	6	60	125	E F	Blown 20 min	130
3408	Sept. 18, 1912	4	60	110	E	Not blown 1 hr	112
3408	May 20, 1914	4	60	110	E	do	110
3542	Mar. 3, 1913	3	60	110	U	Not blown 2 hr. 5 min	108
3578	Sept. 25, 1914	6	60	110	S	Not blown 2 hr. 15 min	102
3542	Dec. 28, 1914	6	60	110	U	Not blown 2 hr	119
3654	Feb. 24, 1915	6	60	110	K	do	98
3716	June 1, 1915	6	60	110	E F	Not blown 1 hr. 45 min	108
3408	Sept. 18, 1912	4	60	100	E	Not blown 1 hr	108
3542	Mar. 3, 1913	3	60	100	U	Not blown 1 hr. 5 min	94
3408	Sept. 18, 1912	6	75	150	E	Blown 60.6 sec	
3674	Oct. 24, 1914	3	75	150	M	Blown 55 sec	
4273	June 29, 1915	4	75	150	B	Blown 2 min. 3 sec	
3654	Feb. 24, 1915	6	75	150	K	Blown 1 min. 19 sec	
3408	Sept. 18, 1912	4	75	110	E	Not blown 1 hr	106
3654	Feb. 24, 1915	6	75	110	K	Not blown 2 hr	98
3408	Sept. 18, 1912	6	100	150	E	Blown 51.6 sec	
3408	Aug. 19, 1914	4	100	150	E	Blown 22.5 sec	
3542	Mar. 3, 1913	3	100	150	U	Blown 3 min. 45 sec	
3674	Oct. 24, 1914	6	100	150	M	Blown 2 min	
3542	Dec. 28, 1914	6	100	150	U	Blown 3 min. 45 sec	
4273	Jan. 29, 1915	4	100	150	B	Blown 2 min. 36 sec	
3654	Feb. 24, 1915	6	100	150	K	Blown 1 min. 33 sec	
3716	June 1, 1915	6	100	150	E F	Blown 1 min. 5 sec	
3408	Aug. 19, 1914	4	100	125	E	Blown 7 min. 45 sec	68
3542	Mar. 3, 1913	3	100	125	U	Blown 40 min. 10 sec	140
3674	Oct. 24, 1914	6	100	125	M	Blown 30 min	
3542	Dec. 28, 1914	6	100	125	U	Blown 1 hr. 35 min	
3654	Feb. 24, 1915	6	100	125	K	Blown 29 min	
3716	June 1, 1915	6	100	125	E F	do	217
3408	Sept. 18, 1912	4	100	110	E	Not blown 1 hr	116
3408	Aug. 19, 1914	4	100	110	E	do	148
3542	Mar. 3, 1913	3	100	110	U	Not blown 1 hr. 20 sec	138
3674	Oct. 24, 1914	6	100	110	M	Not blown 1 hr. 45 min	175
3542	Dec. 28, 1914	6	100	110	U	Not blown 2 hr	117
3654	Feb. 24, 1915	6	100	110	K	do	107
3716	June 1, 1915	6	100	110	E F	Not blown 1 hr. 15 min	140
3408	Aug. 19, 1914	4	100	100	E	Not blown 1 hr	74
3408	Sept. 18, 1912	6	125	150	E	Blown 2 min. 22 sec	
4273	Jan. 29, 1915	4	125	150	B	Blown 4 min. 6 sec	
3654	Feb. 24, 1915	6	125	150	K	Blown 3 min. 48 sec	
3408	Sept. 18, 1912	4	125	110	E	Not blown 1 hr	62
3654	Feb. 24, 1915	6	125	110	K	Not blown 2 hr	109
3408	Sept. 18, 1912	6	200	150	E	Blown 2 min. 22 sec	
3408	Aug. 19, 1914	4	200	150	E	Blown 37 min	
3542	Mar. 3, 1913	3	200	150	U	Blown 5 min. 54 sec	
3542	Dec. 29, 1914	6	200	150	U	Blown 2 min. 5 sec	
4273	Jan. 29, 1915	4	200	150	B	Blown 3 min. 49 sec	
3654	Feb. 24, 1915	6	200	150	K	Blown 2 min. 29 sec	
3716	June 1, 1915	3	200	150	E F	Blown 3 min. 15 sec	
3408	Aug. 19, 1914	4	200	125	E	Blown 16 min	111
3542	Mar. 3, 1913	3	200	125	U	Blown 33 min. 35 sec	144
3542	Dec. 28, 1914	6	200	125	U	Blown 58 min	
3654	Feb. 24, 1915	6	200	125	K	Blown 26 min	
3716	June 1, 1915	6	200	125	E F	Blown 23 min	259
3408	Sept. 18, 1912	4	200	110	E	Not blown 1 hr	95
3408	Aug. 19, 1914	4	200	110	E	do	63
3542	Mar. 3, 1913	3	200	110	U	Not blown 1.25 hrs	89

TABLE 1—Continued

Comparison of Economy and "Approved" Fuses Tested by Underwriters' Laboratories (Inc.)—Continued

250-VOLT FUSES—Continued

Elec. No.	Date	Number tested	Rating	Load, per cent rating	Maker	Maximum time to open circuit	Maximum temperature rise before blowing
			Amp.				°F
3542	Dec. 28, 1914	6	200	110	U	Not blown 2 hrs	120
3654	Feb. 24, 1915	6	200	110	K	do	130
3716	June 1, 1915	6	200	110	E F	do	145
3408	Sept. 18, 1912	6	250	150	E	Blown 58 sec	
3408	Sept. 18, 1912	4	250	110	E	Not blown 1 hr	88

600-VOLT FUSES

3408	Aug. 19, 1914	5	20	150	E	Blown 20.2 sec	
3654	Sept. 8, 1915	6	20	150	K	Blown 45 sec	
3408	Aug. 19, 1914	4	20	125	E	Blown 9 min. 40 sec	62
3654	Sept. 8, 1915	6	20	125	K	Blown 1 hr. 17 min	
3408	Aug. 19, 1914	4	20	110	E	Not blown 1 hr	78
3654	Sept. 8, 1914	6	20	110	K	Not blown 2 hrs	56
3408	Aug. 19, 1914	4	30	150	E	Blown 36.7 sec	
3542	Mar. 3, 1913	3	30	150	U	Blown 45 sec	
3654	Sept. 8, 1914	6	30	150	K	Blown 53 sec	
3716	June 1, 1915	6	30	150	E F	Blown 34 sec	
3408	Aug. 19, 1914	4	30	125	E	Blown 2 min. 15 sec	90
3542	Mar. 3, 1913	3	30	125	U	Blown 7 min. 5 sec	131
3654	Sept. 8, 1914	6	30	125	K	Blown 2 hrs. 10 min	
3716	June 1, 1915	6	30	125	E F	Blown 12 min	64
3408	Aug. 19, 1914	4	30	110	E	Not blown 1 hr. 5 min	64
3542	Mar. 3, 1913	3	30	110	B	Not blown 3 hrs	78
3654	Sept. 8, 1914	6	30	110	K	Not blown 2.5 hrs	108
3716	June 1, 1915	6	30	110	E F	Not blown 1 hr	59
3408	Aug. 19, 1914	3	60	150	E	Blown 35 sec	
3542	Mar. 3, 1913	3	60	150	U	Blown 1.5 min	
3716	June 1, 1915	6	60	150	E F	do	
3408	Aug. 19, 1914	2	60	125	E	Blown 3 min. 15 sec	24
3542	Mar. 3, 1913	3	60	125	U	Blown 12 min. 7 sec	143
3716	June 1, 1915	6	60	125	E F	Blown 20 min	130
3408	Aug. 19, 1914	4	60	110	E	Not blown 1 hr	113
3542	Mar. 3, 1913	3	60	110	U	Not blown 2 hrs	72
3716	June 1, 1915	6	60	110	E F	Not blown 1.75 hrs	138

SHORT-CIRCUIT TESTS

The evidence submitted by the Underwriters' Laboratories indicated that in general the performance of the 250-volt fuses on short-circuit tests was satisfactory, although certain of the 600-volt types were reported as having failed.

It appears from the foregoing evidence submitted by the Underwriters' Laboratories that they have withheld approval of the 250-volt Economy fuse solely because this fuse is designed to be readily refilled by the user; and it has been consistently held by the electrical committee of the National Fire Protection Association that fuses of this character should not be approved because of the greater probability of misuse of such fuses in service than of fuses that are difficult to refill by the user.

IV. REPORT OF HEARING HELD AT BUREAU OF STANDARDS JULY 8, 1915

REPRESENTATIVES PRESENT AT HEARING

A hearing was had on the appeal of Underwriters' Laboratories (Inc.) and Economy Fuse & Manufacturing Co. to the Bureau of Standards, before the following representatives of the Bureau: Dr. S. W. Stratton, director; Dr. E. B. Rosa, chief physicist; W. J. Canada, electrical engineer; Burton McCollum, electrical engineer; H. B. Brooks, associate physicist, and F. W. Glading, associate electrical engineer.

Present on behalf of Underwriters' Laboratories (Inc.): W. H. Merrill, manager; Dana Pierce, electrical engineer; and Darrell S. Boyd, counsel.

Present on behalf of Economy Fuse & Manufacturing Co.: A. L. Eustice, president; R. J. Foote, counsel; H. M. Huxley, patent counsel; Prof. H. E. Clifford, electrical expert; and A. B. Mallory, chief engineer.

Present also: Guy Cunningham, 84 State Street, Boston, Mass., representing manufacturers of approved fuses; H. R. Sargent, General Electric Co., Schenectady, N. Y.; C. E. Skinner, engineer, research division, Westinghouse Electric & Manufacturing Co., Pittsburgh, Pa.; C. A. Bates, electrical engineer, Bryant Electric Co., Bridgeport, Conn.; G. S. Lawler, electrical engineer, and H. O. Lacount, assistant secretary, inspection department, Associated Factory Mutual Fire Insurance Co., Boston, Mass.; Louis W. Downes, general manager D. & W. Fuse Co., Providence, R. I.; Dr. A. S. McAllister, editor, Electrical World, 239 West Thirty-ninth Street, New York, N. Y.; A. F. Daum, Daum Manufacturing Co., Pittsburgh, Pa., and M. Hirsch, assistant examiner, United States Patent Office.

OPENING STATEMENT BY DR. S. W. STRATTON, DIRECTOR OF THE BUREAU OF STANDARDS

Dr. STRATTON. The meeting this morning, gentlemen, marks rather a unique point in the history of the Bureau of Standards. When the Bureau was established its functions were defined in terms sufficiently broad to cover most of the cases that might arise; but necessarily the first effort of the Bureau was confined to the development of standards of measurement, because all standards, whether they be standards of quality or standards of performance, or whatever they are, would necessarily depend upon measurement. It was soon found, however, in connection incidentally with Government purchases that the field of specifications must be entered. Our work of this kind was confined at first to the Government service, and certainly the Government service needed this sort of work. Hence, just as rapidly as consistent with the development of standards of measurement, good work, and the force and equipment at our disposal,

the question of materials was first taken up with a view of assisting in placing Government purchases on a proper and businesslike basis. Of course it was not thought that this would be confined eventually to the Government service, but it was well enough to begin in that way and to work out the standards, methods of measurement, and specifications in connection with our own work.

Likewise, from time to time, almost from the beginning of the Bureau, the Government has insisted that we take up questions pertaining to the performance of apparatus, and for lack of a better term I have frequently referred to this as "standards of performance." This, as you readily know, depends upon standards of measurement and standards of material; both enter into it besides many other complicated questions.

One of the first cases that came to the Bureau from the outside in connection with standards of performance was from the Underwriters' Laboratories in Chicago. There were many conferences between the two bureaus; the work of these two bureaus is very closely related. We were approached by that organization to assist them in the standardization of many kinds of apparatus; that is, we were asked if the Bureau would take the position of passing upon types of apparatus when necessary, which is another way of saying the same thing. There has been a great deal of informal correspondence back and forth, and while the Bureau has been represented on the council and has a word to say in most of their findings, this is the first instance in which the decision of the Laboratories has been referred to the Bureau. It not only marks an important period in the Bureau's history, but, to my mind, is an indication of a change that is going on all over the country, a very important change, and that is, to break away from these exceedingly expensive and senseless legal fights regarding technical matters, nine-tenths of which can be settled if scientific men and engineers will get together and honestly endeavor to find out the facts and to settle the question upon those facts and the facts alone.

We are not yet fully equipped for this work; that must come later. If we are to go into this work in the fullest sense, which I think we shall in time, provision must be made for it by Congress. I believe that will be done, but our disposition is to go as far as we can in the way of assisting the public to bring about these decisions in a fair and equitable way, and that is the object of this meeting this morning. All of the parties concerned have agreed to submit this to the Bureau.

Keep in mind that the Bureau does not expect to be able to settle these questions arbitrarily, not to set itself up as a power above which there is nothing further, but merely the instrument for bringing together all of the facts that exist and for originating such investigations as may be necessary to bring out additionol facts and to verify measurements about which there may be a question. With your assistance and with the assistance of our technical experts throughout the laboratories, we hope to be able to reach decisions of this kind which will be fair and just to all concerned and which will avoid much expensive and needless litigation.

As to the details of this particular case, we are to hear from Dr. Rosa and from Mr. Merrill (of the Underwriters Laboratories) and the manufacturers who are present. Dr. Rosa has organized this investigation by the appointment of a committee of the men in the Bureau who are deemed to be the best equipped to handle it, and he will now tell you of the methods they have pursued, and in a general way will conduct the investigation with the aid of this committee.

STATEMENT OF DR. E. B. ROSA, CHIEF PHYSICIST OF THE BUREAU OF STANDARDS

Dr. Rosa. The matter before us for consideration to-day is an appeal from decisions of the Underwriters' Laboratories concerning a certain make of refillable cartridge fuse. The case was brought to the Bureau on May 13 by the Economy Fuse & Manufacturing Co. and the Underwriters' Laboratories, jointly. The object of the public hearing of to-day is, first, to enable the Bureau to state to the manufacturers of various types

of inclosed fuses, and others interested, the manner of conducting the appeal, indicating the kind of evidence which has been supplied to the Bureau and the independent studies and inspections that are being made by the Bureau; and second, to give manufacturers and inspectors and the public generally an opportunity to submit additional evidence bearing upon the question. The Bureau is, of course, very anxious to have the fullest information on both sides of the question.

At a meeting held in Chicago on May 27 between representatives of the Bureau of Standards and of the Economy Fuse & Manufacturing Co. and of the Underwriters' Laboratories, it was arranged that a public hearing should be held at the Bureau of Standards on the subject under consideration, to which hearing the manufacturers of all types of cartridge fuses should be invited as well as the electrical inspectors of the various insurance organizations and municipalities. It was understood that all evidence submitted or statements made should be checked or investigated by the Bureau as it sees fit, and that the Bureau should make any independent experiments or inspections that it may think necessary. The question as formulated jointly at this meeting is as follows:

Has it been shown that the use of the fuses manufactured by the Economy Fuse & Manufacturing Co. results in no greater fire or accident hazzard than the use of other cartridge-inclosed fuses at present listed as standard by Underwriters' Laboratories?

"Has it been shown that" was understood to mean "Has it been shown by the manufacturers of the Economy fuse, by the testimony of users and inspectors, by the experiments and inspections of the Bureau of Standards, and by all other evidence available, including that offered by the manufacturers of other fuses, that," etc.

The question has reference only to ferrule and knifeblade types of fuses of 400 volts and under, these types having been tested and reported upon by the Underwriters' Laboratories. (This was modified later to include 600-volt fuses, as stated in the résumé of the work given at the beginning of this report.)

On June 10 a circular letter was sent out by the Bureau of Standards announcing the hearing and the question under consideration, and stating that written communications would be received by the Bureau in lieu of personal attendance from anyone having information bearing on the question at issue. The Economy Fuse & Manufacturing Co. has placed in our hands a considerable number of letters, affidavits, and other material, and the Underwriters' Laboratories have supplied us with the results of a large number of tests conducted by them on various types of inclosed fuses. The Underwriters' Laboratories also made a series of fuse tests in our presence, to show the details of the method of testing and the performance under severe conditions of test of a number of different makes of inclosed fuses, of several different capacities, including both refillable and nonrefillable types.

We also have the results of a large number of tests, made upon different types of inclosed fuses by a disinterested testing laboratory, the tests having been made for the manufacturers of the Economy fuse. The company that made these tests stipulated that the results should not be published, and that it should not become involved in any controversy over the question, but it has supplied the Bureau of Standards with a copy of the tests and the results obtained for its information in connection with this case. These tests include a very large number which were made with an oscillograph in circuit in such a way as to measure the instantaneous values of the current and of the voltage at the terminals of the fuse, and to show in each case the duration of the process of blowing the fuse; i. e., they show the time elapsing from the instant the current begins until it ends, and also the time from the moment that the fuse melts and the arc begins (when the voltage suddenly rises) until the current ceases. The resistance in the circuit was recorded in each case and the reactance in most cases, and the curves show the effect of reactance upon the duration of the momentary current which blows the fuse. These tests were made under extreme conditions of short circuit, the kilowatt capacity of the source of current being very great and the resist-

ance very small, in some cases the instantaneous current blowing a 100-ampere fuse being more than 10 000 amperes and the duration of the current less than 0.01 of a second. We have measured on these curves the instantaneous values of current and voltage, and thereby obtained the instantaneous power in kilowatts which, integrated through the period of blowing the fuse, gives the total amount of energy expended upon the fuse. We have done this upon 50 or more oscillograph records for six or eight different makes of fuses, all of the same rating, and have thus obtained some very interesting information. In some makes of fuses, the duration of the blowing of the fuse is very much shorter and the energy expended less on an average than in other makes for the same capacity of fuse. Wherever an arc persists the oscillograph records it accurately, and some makes of fuse show a greater tendency than others for an arc to persist for a few hundredths of a second.

We have also made experiments in our own laboratories on a considerable number of fuses of several different makes. The source of current had smaller capacity and the resistance was greater, the conditions corresponding more nearly to average working conditions than the test just mentioned, which was made under extreme short-circuit conditions. Instead of an oscillograph to record the instantaneous current and voltage we have used a wattmeter with a weighted needle the deflection of which is momentary (like a ballistic galvanometer) and which integrates the power for the period of blowing the fuse, thereby giving in a single deflection a measure of the energy expended upon a fuse. It has been very interesting to compare the wattmeter deflections, which are proportional to the energy, with the noise and character of the explosion accompanying the blowing of the fuse. Some makes of fuses are much more uniform in their behavior than others, and there is a considerable difference in the average amount of energy required to blow the different makes of fuses of a given capacity, as was stated above in the experiments made in another laboratory where the oscillograph records were taken. On alternating current the same fuses vary widely in the violence of blowing, according to whether the current is broken when there is a large amount of energy in the alternating-current circuit or a small amount, i. e., it is a matter of chance as to whether the current or voltage is large at the moment that the fuse melts and is interrupted or whether it has an intermediate value or a zero value. Hence, the energy and violence of the explosion may vary through wide limits on fuses which are identical in construction. This well-known fact is clearly explained by the oscillograph records. A very large amount of other information has also been obtained from the laboratory experiments which have been made here in the Bureau and at the other laboratory referred to. These facts are cited here in order to show that the consideration of this question is being made in the light of full experimental evidence.

We have also consulted with a considerable number of insurance and municipal inspectors, and have some specimens of cartridge fuses of various makes that have been collected by these inspectors in the course of their work which have been improperly refilled or made inoperative. We have received some letters from such inspectors in addition to those which have been supplied by the appellant company. In order to secure some first-hand information with regard to the use of cartridge fuses, we have visited a number of establishments where a considerable number of fuses are used and which employ competent engineers to take care of the electrical machinery and to handle the fuses, and have secured their experience in the use of different types of cartridge fuses. We have also visited a large number of places in several different cities where fuses are used on lighting and small power circuits and where no competent attendants are employed. It has sometimes been stated that refillable fuses are more likely to be improperly used in sweatshops and other places of a similar nature than is a nonrefillable fuse, and that any type of refillable fuse would for that reason be more subject to misuse and constitute a greater life and fire hazard than a nonrefillable fuse. In order to secure information at first hand upon this subject, we

have given it special attention in these inspections, and have secured a large amount of very important information and a considerable number of samples of misused fuses in so doing. Further inspections of this kind will be made by the Bureau and the testimony of inspectors will be welcomed.

It is proposed to hear to-day any statements having a direct bearing upon the question at issue from anyone who wishes to be heard. Unsupported opinions or statements from interested parties will, of course, have very much less weight with the Bureau than testimony of disinterested parties or proof of improper use of fuses, or accidents or damage which had been caused by particular types of fuses. We have received a large amount of testimony from disinterested sources favorable to the Economy fuse. We particularly desire similar disinterested testimony from those whose experience is unfavorable to the Economy fuse, if there are any considerable number of such persons. We understand that about a million of these fuses are in actual use at the present time, some of them having been in use several years. In many cities their use has been permitted for the express purpose of acquiring experience with them, and many municipal and insurance inspectors have been on the lookout for trouble. Hence, if serious trouble has frequently occurred, it ought not to be difficult to secure disinterested testimony concerning it. Statements in rebuttal of anything said to-day may be made in writing at any time within 15 days. [This date was later extended to October 15.] All such statements, together with the information and testimony submitted heretofore or brought out to-day will be taken into careful consideration by the Bureau in making up its opinion. It is proposed to give a rather full digest of this evidence in connection with the decision, in order that the public may have sufficient ground on which to form an independent judgment of the merits of the case.

STATEMENT OF W. H. MERRILL, MANAGER, UNDERWRITERS' LABORATORIES (INC.), CHICAGO, ILL.

Mr. MERRILL. Mr. Director and members of the staff of the Bureau of Standards, I feel that to-day you are making history. More than two years ago we came to Washington and outlined a plan, to which Dr. Stratton has referred, and secured the assent of the Director to serve on the council and permission to file our records with the Federal authorities as represented by the Bureau. It was my hope and expectation that a practical demonstration of the method of appeal you have arranged for would come about within a few weeks or months, or a year at the latest. That it has not done so, perhaps, reflects some credit on the opinions which we have registered in respect to many devices which have come before us during that time. The method of appeal arranged for and beginning with the practical demonstration to-day has been free to any manufacturers who have been in dispute with us. It has been favorably accepted previous to this instance, by three, who, after consideration of the questions involved, failed to exercise their privileges and agreed to the statement of facts as we found them in respect to their appliances. It had seemed to me when this matter was first discussed, and it seems to me to-day, that no branch of the Federal Government can perform a more useful service than to quickly and intelligently and adequately and comprehensively settle matters in dispute between various citizens of the country. Just as it is my privilege as a taxpayer to come here with my grocer's peck measure or my dry goods merchant's yardstick and ask, with his consent, that this peck measure or this yardstick be compared with the standard for the information of the two of us, as taxpayers who are in dispute as to whether I am really getting a whole peck or a whole-length yard, so I conceive it is the privilege of the Underwriters' Laboratories, a corporation of Illinois, and any manufacturer or any one of its clients to come here and ask the privilege of the same service in matters of a technical nature in dispute between them on which the constituted authorities are equipped, through this Bureau, to give an intelligent opinion. And, as the Director

has said this morning, it is very much in the interest of the people to have a tribunal on matters of this kind that understands something about what the litigants are trying to talk about.

When you go into the legal machinery of the States and of the Nation, you are met with long delays prejudicial to the interests of the manufacturer who may be seeking redress. In certain of the courts you have to face juries, not of intelligent, educated men versed in the science of the particular thing that may be under consideration, but such men as are picked up in the street or chosen by raffle of some kind.

Another very agreeable thing, I believe, to all persons interested in this movement is the fact that underwriters' laboratories and other laboratories that may seek this privilege, and other largely disinterested persons—as, for instance, the municipal authorities and the various State authorities that are called upon to pass upon questions of this kind—have no selfish interest in the matter of their decision. They have nothing to gain by a wrong decision. They are only interested to get at the facts, and therefore the formalities of the court and the technical advantages that are sometimes taken through legal procedure, and all that sort of thing, can well be done away with as having no interest whatever to the people who come here seeking the one best opinion on a technical matter. There is but one such opinion; there can not be two opinions, one at variance with the other; one is bound to be wrong. It is only necessary to get all the data, to sift all the evidence that is presented, if the tribunal is competent to measure its importance, and to pass intelligently on the technical questions involved.

We feel very strongly that we have such a tribunal in the Bureau of Standards, of which all the people of the country ought to be very proud. We feel that this hearing to-day and others of a similar character which may come in the future, through our laboratories or other laboratories or State or municipal officials, who on their own account have no means of determining some of these questions and must go at it in a more or less haphazard way—we feel it is going to mark a great advance in a movement that will prove of service to every property owner of this country, because a wrong decision by a local authority, a State authority, or the Underwriters' Laboratories may last for some brief length of time, and it may do an injury both to the property owner and to the manufacturer of the appliance. But it can not last very long; nothing that is wrong eventually prevails in America. My experience is that those mistakes that are made by inspectors, laboratories, State and city officials and others, all rectify themselves in time; the facts come out; but there has been no generally utilized machine to bring those facts to the surface promptly and intelligently. It has been a long process sometimes to bring them out by the light of field experience and through the article itself ultimately proving its value or lack of value.

I am principally interested here to-day in this movement as a matter of policy and as a step in advance, not only as it affects electrical appliances but as it affects fire extinguishers, fire retarding appliances, and all sorts of manufactured articles that may have any bearing on life or accident hazards. This particular case is merely incidental.

I thank you for the privilege of going on record to-day in expression of the opinion I gave informally two or more years ago.

So far as this particular case is concerned, I would like to ask the privilege of presenting our side of it after we have heard the full presentation of the manufacturers' side, and give way to Mr. Foote for his presentation of the case.

STATEMENT OF R. J. FOOTE, COUNSEL, ECONOMY FUSE & MANUFACTURING CO., CHICAGO, ILL.

Mr. FOOTE. Mr. Director and members of the Bureau. At the outset I would like to say that the Economy Fuse & Manufacturing Co. have appreciated the importance of this hearing as an initial proceeding of this kind, and while the contention of the

Laboratories is a very narrow one from a personal point of view, we have endeavored to approach it from the larger viewpoint of a general consideration, as far as the Bureau of Standards is concerned, of the fire hazard in connection with fuses, that being involved in the particular dispute which we have. This company has honestly been engaged in the endeavor to correct an evil in the use of fuses and to build a fuse which should be the best of its kind that ingenuity and experimentation along scientific lines could produce.

That has been our aim, and we have endeavored in every possible way and spared no expense to gain that end. For that reason, in submitting our case to this Bureau, we have endeavored to make it an investigation, not a personal presentation; and we have submitted to the Bureau heretofore, at the preliminary hearing in Chicago, all the information which we were able to gather, whether it was for us or against us, and any scrap of paper we have had which was in the nature of a fact or an opinion based upon fact has been submitted to this Bureau.

But, of course, we do have a very definite question presented here for a very definite answer which has a very material meaning to us, and in the light of the fact that this is in the nature of an arbitration, there is just one thing I would like to have understood. That is that in order that it may be fair to us, as we have thrown open the doors to the world and stand alone against everyone, to bring in any sort of evidence, any sort of statement, any sort of opinions which will have weight in the determination of this question, limited to statements of fact or opinions based thereon, those facts to be in such shape that we, the Economy Fuse & Manufacturing Co., may in the time allotted in our agreement with the Bureau investigate their accuracy or truth. In other words, if there are statements made here based upon the misuse of the fuse, it is my desire to know the name of the plant where the occurrence arose, and the time, and the man who gives the testimony.

Of course we have been over some of this with the Bureau, but it seems to me, in view of the large interest which is taken in this subject, that it is worth while (with the Bureau's consent) to outline completely the evidence which we have to offer and our argument thereon. The question submitted for determination is one of fact. It is:

Has it been shown that the use of the fuses manufactured by the Economy Fuse & Manufacturing Co. results in no greater fire or accident hazard than the use of other cartridge-inclosed fuses at present approved by the Underwriters' Laboratories (Inc.)?

These other fuses are the following:

"Buss"..... Bussman Manufacturing Co., St. Louis.
"G. E."..... General Electric Co., Schenectady, N. Y.
"Union"..... Chicago Fuse Co., Chicago, Ill.
"Arkless"..... Detroit Fuse Co., Detroit, Mich.
"Shawmut"..... Chase Shawmut Co., Newburyport, Mass.
"Killark"..... Killark Electric Manufacturing Co., St. Louis, Mo.
"Noark"..... Johns-Pratt Co., Hartford, Conn.
"Bryant"..... Bryant Electric Co., Bridgeport, Conn.
"D. & W."..... D. & W. Fuse Co., Providence, R. I.
"K. E."..... Kirkman Engineering Co., New York City.
"Metropolitan"..... Metropolitan Engineering Co., Brooklyn, N. Y.
"Multi"..... Multi Refillable Fuse Co., Chicago, Ill.
"United"..... United Electric Supply Co., Brooklyn, N. Y.
"Westinghouse"..... Westinghouse Electric & Manufacturing Co., Pittsburgh, Pa.

There are some few others, but they are, so far as we have been able to learn, used so little that samples are not readily obtainable. The principal ones are those which I have named, and samples of each of those fuses are here before you.

Each of the foregoing fuses is approved by the Underwriters' Laboratories (Inc.), and the question is whether the use of Economy fuses results in no greater fire or

accident hazard than the use of any one of the above named; not some or a favored one or two, because the question is whether the Economy fuse is being discriminated against on the question of the relative fire hazard involved in the use of the devices.

This question arises because, as will be found on reading the communication of the Economy Fuse & Manufacturing Co. of April 2, 1915, to the Underwriters' Laboratories which gave rise to the question here, it was shown that many of the above approved fuses are so designed and constructed as to permit the ready replacement of the fusible element, especially in the knife-blade types, and the reassembly of the fuse without injury to any of the parts by the user; which results in a positive invitation to the user to refill, irrespective of the so-called announced intent of the design, especially as many of the fuses bear a printed label that the fuse will be refilled by the maker, and one company calls itself "Multi Refillable Fuse Co." The Laboratories themselves in their published list state that their approval extends to fuses refilled by the maker.

The samples of the fuses above mentioned are submitted to the Bureau to show from simple inspection how easily they can be renewed. It is not claimed that these approved fuses as renewed by the maker are tested for safety of operation, and an inspection alone of the fuses shows that they are not so ruggedly constructed as to stand repeated renewal, even when skillfully done. It is also apparent from inspection that the omission of the filling material on reassembly would be dangerous because of the open ventholes and very thin caps.

What I am giving now is simply a general statement of our case. Following that I wish to call attention to the general extent of the use of the Economy fuse. The company has 7080 direct customers at this time, and we have furnished the Bureau with a full alphabetical list of those customers. The diversity of use will be found from an inspection of that list. The Economy fuses are in daily use in all States of the Union and throughout Canada; some in Russia, Germany, France, and England, and in Argentina, South America. The character of the users will be found to embrace every kind of industrial installation, large and small, steamships and railroads. The Economy fuses have been in service for three years.

The extent of the use is evidenced by the number of Economy fuses in actual service. Without going into too much details, there have been approximately 500 000 of the ferrule type without any filler, and some 400 000 of the ferrule type with the old filling material. That is the type we were debarred from making some two years ago.

There were 90 000 of the knife-blade type with the filler or with the asbestos sleeve, both of which have long since been discarded; and 130 000 of the knife-blade type without the filler, giving a total number of 1 120 000.

The frequency of operation is shown by the sale of renewal links which have been furnished by the company, which amount to 3 632 000.

Fuses of older types, with filling material or with asbestos sheathing over the link, are rapidly disappearing and being replaced with the latest type with the free drop-out link fuses, or air-space fuses. A good many of those old types have gone out of use entirely.

The comparative cost of fuses and the cheapness of Economy renewal elements and the ease of refilling and reassembly are important. The example taken is the most extensively used size, 100-ampere knife-blade type, 250 volts.

A comparison there shows that the present cost of approved nonrefillable fuses, new, is 40 cents. That was recently reduced, as I understand it, by a circular, to 24 cents, but since that time, I understand, the price has gone back to almost 40 cents—38 cents.

I want to make our comparison on the basis of the 24-cent price. The cost of refilling by the maker, as advertised by the maker, is 16 cents, not including the returning in standard packages for refilling, the return to the user, nor the cost of assembly.

The cost of an Economy fuse of the same type is 90 cents, with two renewal links, or three operations at 30 cents each. The renewal links cost 5 cents apiece, and we have instances of Economy fuses being renewed as many as 75 times in actual use. Taking an average of 10 renewals, which no approved fuse will stand, the cost to the user is 13 cents apiece. As against that, 10 blow-outs of approved fuses, with the utmost refilling by the maker which the fuse shell and parts will stand, which would be not more than three times, would make the cost 19 cents apiece.

Extent of use and relative cost are important factors. Such widespread use by such important, carefully conducted industries could not be possible in the face of the enormous opposition the company has encountered from certain insurance organizations of nation-wide activity, and from competitors who have left no stone unturned to stop the growth of the company's business, if, as it is alleged by some, the Economy fuse is a fire hazard and a dangerous device, and their use takes the answer to the question submitted out of the realm of the imagination and opinion and reduces it to an easily ascertained fact.

The comparison of cost shows the reason for the constantly recurring statement that the high cost of renewals is one of the chief causes of the dangerous practice of refilling so-called nonrenewable fuses and that the cheapness of Economy renewal links—as cheap as one-half cent in the small sizes—and ease of insertion are what tend to reduce or eliminate this dangerous practice.

The making and selling of cartridge-inclosed fuses has been a large, profitable business, controlled for years by a few strongly intrenched companies, practically all operating under licenses from one patent owner. It is, to those who know the real facts of the fuse situation, not surprising that the entrance into this supposedly well-walled field of a device for which there has long been a crying need, and one which was designed to overcome the very evils long recognized as flowing from the use of then known devices, should provoke a storm of criticism and engender opposition from every possible quarter from which it could be made to come.

The imagination has been racked and opinions based thereon emphatically stated as facts, often innocently, often intentionally, to injure the Economy fuse, until if the Economy fuses from actual experience with their use secured under the most exacting conditions of watched use by insurance inspectors, unknown to the users, had not completely demonstrated the fallacy of all the imaginings and expert opinion based thereon, and proved that they do correct the evils attendant on the use of approved fuses to at least some extent, the Economy Fuse & Manufacturing Co. would have ceased to exist long ago.

Therefore we say the answer to the question submitted is not to be determined by the announcement of opinion, expert or otherwise, no matter how vehement, when not based on the facts of experience.

It is these facts of the experience of users of the fuses and of insurance inspectors who have, without the knowledge of the user, carefully watched their use with the preconceived notion that there were dangers to be overcome which must determine the question and which are submitted herewith.

Before setting forth the facts it should be borne in mind that there is a vast amount of real ignorance existing in regard to the dangerous operation of fuses when new and the causes therefor, and that much faulty fuse operation is due to defective cut-out blocks and unknown circuit conditions, which sometimes results in the use of a certain type of fuse under conditions it was not constructed to meet.

We do not contend that the use of the Economy fuse will prevent intentional overfusing, because in that case a fuse is not desired. They want a continuous circuit, and it would be absolutely impossible to devise any fuse which would prevent bridging; even if the caps were made so that they were insulated, which could be done, it is not protected at all, because they solder a wire right across the terminals, which is a very common practice, or solder across from the actual copper terminal plates. So there is no way to prevent that.

The evidence we have submitted to substantiate the statement I have just made consists of some 15 volumes which I have filed here, which have been accessible to the Department for checking for some time, and I will read some of them. First, I want to give the general synopsis of the argument.

The reason the question submitted here arises is because of two contentions on the part of the manufacturers of so-called "nonrefillable" fuses of the cartridge-inclosed variety, to which class the Economy fuse belongs, and these contentions are as follows:

First, that an inclosed cartridge fuse, such as the Economy, will not, when properly assembled, operate in test, in practice on the initial blow, or after repeated renewal as safely as the nonrefillable type.

Second, a fuse of the Economy design, which invites refusing and reassembly by the ordinary person must of necessity be in use so susceptible to improper reassembly as to render it a distinct hazard as a device.

It must follow, therefore, that if the Economy company can show that the Economy fuse, as assembled at the factory and put in the hands of the users and as reassembled by them, in accordance with the directions of the company, operates at least as safely both in test and in practice as any other cartridge-inclosed fuse—and that while the Economy fuse is, of course, susceptible to improper assembly, that so also are the so-called "nonrefillable" types, and the actual fact is that they are in practice no more frequently in any way improperly assembled than are the present so-called nonrefillable types—then it has been shown that the use of Economy fuses constitutes no greater fire hazard than the use of the present inclosed fuses listed by the Underwriters' Laboratories.

If it is further shown that the undeniable tendency in the use of Economy fuses is to reduce the practice of overfusing in a great majority of unintentional cases, and that by its use, on account of its special features as to ease of assembly and price, the greatest incentive for overfusing is removed by removing the causes of cost of carrying a sufficient stock and lack of accessibility of stock, then it has been further shown that the Economy fuse not only is not a greater fire hazard than the present types of approved inclosed fuses but is a distinct safety device.

To substantiate those two claims in general we point out the following evidence: On the first point we refer to the Underwriters' Laboratories' tests and reports, of which there are three. We refer to the tests made by disinterested experts, with which the Bureau is familiar, involving the blowing of something over 3000 fuses, covering a period of two or three months, in the hands of as skilled individuals as it is possible to obtain and under the most exacting conditions. We refer to the evidence of over 800 users of the fuses. We refer to the evidence of 40 of the principal insurance inspection departments in the country. Those inspection departments cover the entire United States in general, with the exception of the New England States.

To substantiate the second contention—that is, that the Economy fuse is no more improperly assembled than the approved fuses are improperly assembled—we submit the following: The first proposition to be established in regard to that is that the approved refillable fuse is abused, and that that abuse is prevalent. To substantiate that we refer to the Underwriters' Laboratories' report of the evidence furnished them from manufacturers, statements of insurance inspection departments, and statements of users, which show that over 42 per cent of the general users of fuses attest that they refill. Third, and last, any ordinary investigation by anyone seeking the information.

The reasons for this abuse are either intentional—which can not be stopped with any make of fuse, because a fuse is not desired but a continuous circuit—or unintentional, which is due primarily to the cost of replacing frequent blow-outs with new fuses and to failure to have proper fuses handy, in each the cost leading to a

reluctance to carry a sufficient stock to be prepared for all emergencies, or, even though the stock be carried, the unwillingness of workmen to go too far to get a fuse for replacement when the stock is not accessible.

The renewal principle alone applied to any fuse is not susceptible of discussion on the question of the reduction of the fire hazard in view of the known conditions, because there is no comparison between an actual nonrefillable fuse and refillable one, the fact being that all fuses as at present designed are of the refillable sort, the difference being only one of degree as to ease of refilling and of cheapness as to the cost. For that reason the question submitted is not one of refillable fuses against so-called nonrefillable fuses, but as to whether the Economy refillable fuse, by reason of its special refillable features, constitutes any greater fire hazard than the use of other types of fuse.

The prime essentials, then, in considering the question from this aspect are as to whether the present refilling and abusing of the present approved nonrefillable fuses are in a measure eliminated by the design and construction of the Economy fuse, and as to whether in their use the fact of this design and construction and the furnishing of the parts at a cheap price does, in fact, tend to cause the fuse to be properly renewed so as to lessen the improper renewal, bridging, etc., practiced with the so-called nonrefillable type.

A simple inspection shows that all the fuses with which comparison is being made are easily renewable, some being more easily renewed than others; that the invitation to renew is always present, either from the very nature of the design or from the fact that the fuse bears a label stating that it may be renewed, or the name of the manufacturing company indicating a renewable feature.

Now, to go back to the first proposition, that the Economy fuse as assembled at the factory and put into the hands of the users, and as reassembled by them in accordance with the directions of the company, operates at least as safely, both in test and in practice, as any other cartridge-inclosed fuse. The first submission of our fuses to Underwriters' Laboratories was in the summer of 1912. That was when the fuses contained the filling material and had a different design of cap; that is, the cap screwed down onto the fiber. I wish to say here that that design was found to be faulty. We had frequent and numerous complaints in regard to the charring of the fiber where the cap screwed onto it, and for that reason we eliminated that feature of the fuse and fastened the cap permanently to the end so that that could not occur.

Almost every complaint in this great mass of evidence we have, of which there are 28 out of some 800 or 900 as to unsatisfactory performance, is traceable to that feature which has not existed for about 18 months. There are some still in use, for the reason that we could not deprive some users of that kind of fuse, because there are men who believe that a filling material is an absolute essential to the safe operation of the fuse, and you can not convince them otherwise.

The fuses submitted in 1912 were of that type, with the filling material which was objected to, and upon them the Underwriters' Laboratories made a very full report. I do not know whether it is necessary to call attention to the rating test, because as to rating there has never been any dispute, and the Economy is probably at least as well rated as any well-known fuse. There is nothing to disprove that, except the reports we have from many users that it has been underrated. Their report of the result of the short-circuit test was as follows:

> *Short-Circuit Test.*—In every test in which the fuses were properly assembled, the devices opened the circuit promptly, did not hold an arc, and gave no external evidence of operation except a slight puff of the filling powder. While the operation of the unfilled fuses was not as good as that of the filled fuses, particularly as to venting and noise, the results compared favorably with those obtained with standard approved fuses tested at the same time.

That is, Underwriters' Laboratories in their first report on the design of fuses reported, after a severe test, to which they subject all fuses or other material sub-

mitted to them, that the fuses as properly assembled gave no evidence of operation except a slight puff; that then, to make sure, they took the filling material out (and at that time our fuse was designed with that end in view) and operated it under test conditions and found that its operation then compared favorably with the other approved makes of fuses, and so reported.

In November, 1913, an injunction was issued against us on the use of a filling material in the fuse. In October, 1913, we designed a fuse without the filling material, and no filling-material fuses have been used since October, 1913, except those possibly that had been sold previous to that time, of which a great many had been replaced. Those were submitted to the Laboratories during that winter. Of course the Laboratories are busy and it takes them some time to get out a report, even after they make a test; and their report on the ferrule type of fuse without the filling material, which is the present design, was dated May 20, 1914. Their report was as follows:

> *Short-Circuit Test.*—In every test the devices opened the circuit promptly, did not hold an arc, throw out melted metal or flame, and gave no external evidence of operation except a slight hissing or puffing sound. In every test the double-notch links opened at each notch and left the center section of the fusible element intact.

At that time we were using, with the consent of the Johns-Pratt Co., the asbestos sleeving over the link in the ferrule type. For a few months we did that until our design without any filling material or asbestos sleeving of any shape was completed, so that while the design with the ferrule was in use from May 1, 1914, when we put in the knife blade without the sleeving or the filling material, prior to that time there had only been 90 000 of the ferrule type sold. Therefore the amount of those with the filling material or the sleeving in use is comparatively insignificant, because the great bulk have been sold since November, 1914, which are of the present design submitted here, and that is the design upon which the Laboratories reported in September, 1914, the first report being on the ferrule type only. And as to that they say:

> *Short-Circuit Test.*—In every test the fuses opened the circuit promptly, did not hold an arc, throw out molten metal or flame, and gave no external evidence of operation, except a slight hissing or puffing sound.
>
> In every test the double-notch links opened at each notch and left the center section of the fusible element intact, while the four-notch, 600-volt links opened at each notch, dropping out three sections intact.
>
> The number of samples tested are shown by the following table.
>
> * * * * * * *

On the renewal of the fuses:

> It is judged that the probability of these fuses being assembled improperly is less than of the earlier type requiring a powdered filling material.

So that the dispute between the Laboratories and ourselves, as I think, has been made clear in the talk of Mr. Merrill, preceding my own, and is not one of test performances or the possibility of proper assembling and then proper operation on renewal after assembling, but it is on the question as to what does the use show as to improper assembling of these fuses resulting in improper operation, and it is that question which, of course, the Laboratories can scarcely pass upon, as to the dispute between ourselves as manufacturers and the other manufacturers, without showing some degree of partisanship.

That brings us to the real question at issue, which is that while the Economy fuse is susceptible of improper assembly, the fact is that every fuse on the market is equally so susceptible, and that they all are improperly used or refilled, both the Economy and the other types; but that the fact also is that when you examine into the incentive or the reason for that practice and then show that you remove that reason, that your results which you obtain from the users conclusively show that the Economy fuse is

less often improperly refilled than an approved fuse is abused, and that it does in fact do away to a considerable extent with both the unintentional and the intentional abuse of the fuse—the unintentional because all reason is removed and the intentional because a lot of intentional overfusing is because of the cost of the fuse or getting one, and the renewable fuse which is easily and cheaply renewed, interrupts the service for a short length of time and that they are glad to get the protection and not make a short circuit; and that is shown by the answers which Ishall read in a few minutes.

Before we get to the evidence of the users on that question I should like to read some of the statements from the insurance inspection departments on this question. First, I want to say that on that we have here the statements in the form of affidavits in a number of cases and statements simply in the form of letters in others of inspection departments as follows, showing the very wide territory that is covered: The cities of Chicago, Ill.; Cincinnati, Ohio; Indianapolis, Ind.; Cleveland, Ohio; Portland, Oreg.; Nashville, Tenn.; Grand Rapids, Mich.; Colorado Springs, Colo.; Chattanooga, Tenn.; Denver, Colo.; Duluth, Minn.; Superior, Wis.; Minneapolis, Minn.; Philadelphia, Pa.; Buffalo, N. Y.; and New York, N. Y. We also have statements from general insurance organizations, such as boards of fire underwriters, State boards, and those embracing a large number of States. The union, which embraces some 90 of the largest insurance companies operating in the Central West, and the report of the inspector who makes the statement which covers the entire central western section, and, as will be noted when I read it, he is consulted by men in all that territory: Kentucky Actuarial Bureau, Ohio Inspection Bureau, Wisconsin Inspection Bureau, Michigan Inspection Bureau, St. Louis Fire Prevention Bureau, Chicago Board of Fire Underwriters, Tennessee Inspection Bureau, Cincinnati Fire Prevention Bureau, Rocky Mountain Fire Underwriters Association, Allegheny County Board of Fire Underwriters, Canada Fire Underwriters Association, Southeastern Fire Underwriters Association, Underwriters Association of the Middle Department of Philadelphia, Minneapolis Underwriters Inspection Office, Underwriters Association of New York State (which has its headquarters in Syracuse), and also the Underwriters' Board of New York City. While we have not the statements from them here, they have, I think, written the Department that they will be glad to furnish the results.

We also have affidavits which came in later from the chief of the fire department of Antigo, Wis., the chief of the department of electricity, city and county of San Francisco, and the chief inspector of General Inspection Co., Minnesota and Dakota, and from village electricians.

As covering the whole situation, the affidavit of Mr. Tousley, I think, is very interesting, because involved in his territory are something over 120 000 inspections in a year. He is the chief inspector of the department of gas and electricity of the city of Chicago, and with the permission of the Director, I will read the affidavit. (Reading.)

STATE OF ILLINOIS, }
COUNTY OF COOK, } *ss.*

Victor H. Tousley, being first duly sworn, deposes and says that he is the chief inspector of department of gas and electricity in the city of Chicago, Cook County, Ill.; that he has been in the service of the city for 17 years, as follows: Three years inspection of outside work, 10 years as inspector of interior wiring, and 4 years as chief inspector. That the department has jurisdiction over all exterior and interior wiring within the limits of the city of Chicago.

Affiant states that there are 52 inspectors, assigned as follows: Twenty-eight in districts, 8 on reinspection, 2 on the inspection of electric signs, 3 on the inspection of outside work, 1 on the inspection of theaters, 3 in the department laboratory, and the balance on investigations and special work. The 28 district inspectors cover the inspection of all interior work on new installations within their respective districts. They also investigate all fires and all accidents due to electricity and make some reinspections of old installations. The men assigned to reinspection make periodic reinspections of old buildings which contain considerable electrical apparatus. The men assigned to the laboratory cover the investigation of electrical apparatus and make special investigations of wiring

methods and devices. The other divisions are described in their titles. The inspectors make all reports in writing and otherwise follow the usual procedure of municipal inspection departments.

Affiant further states that reports received from the inspectors, both written and verbal, as well as personal investigation made by this affiant, show that since the inception of what is known as the "inclosed" fuse considerable difficulty has been encountered in maintaining these fuses in accordance with the Code requirements for the same. It has been found that these fuses have been altered by inserting fuse wires of larger size, copper wires, or other conductors through the interior of the fuse; by attaching fuse wire, copper wire, or other conducting materials on the outside of the fuse inclosure; by the provision of "jumpers" of fuse wire or other metals around the clips of the fuse block and by the construction of conducting materials to be placed in the receptacle provided for the fuse, the results of which have been that the fuse was either made inoperative as a fuse or rearranged in such a manner as to constitute a hazard.

I might say, there, that it is not the operation of the fuse that constitutes the hazard; it is the lack of the fuse or the operation of the fuse that makes the hazard. It is not the places where the fuse blows where the burn occurs, but the current is allowed to get through and burns out machinery or the wiring in some other place, which causes the fire hazard, in the majority of caases, although we have examples of occasional burning of fuses. Bus fuses are usually protected either in iron cabinets or in a place where it does not cause any great amount of actual damage, so that that goes directly to this question of fire hazard in connection with the use of the different kind of fuses as far as the test operation is concerned.

Affiant further states that as a result of the hazardous conditions brought about by the above the department of gas and electricity of the city of Chicago, in conjunction with the Underwriters' Association of Chicago, formulated, and for the past eight years has enforced, a rule forbidding the installation of "inclosed" fuses unless inclosed in a standard fireproof cabinet as provided for by the Code for strip fuses.

Affiant further states that in order to obtain knowledge regarding the fuse situation the department has for a number of years made various special investigations of the use and abuse of "inclosed" and other types of fuses. Since the type of fuse known as the "renewable" or "refillable" has appeared on the market, this department, in order to obtain knowledge of the experience with this type of fuse, has permitted the use of the fuse manufactured by the Economy Fuse & Manufacturing Co., with no restriction except that the department should be informed as to the name and address of the parties to whom such fuses were sold, the purpose of this stipulation being to provide the department with the means of carefully investigating the use of this fuse. The fuse manufactured by the Economy Fuse & Manufacturing Co. has been in use under the conditions mentioned above for a period of two years. During this period systematic investigations have been made of the use of the above-named fuse by an inspector of this department specially chosen for knowledge on the subject. In these investigations an effort has been made to consult all classes of persons using the fuse, paying special attention, however, to those men in charge of the larger plants whose ability and integrity could not be questioned. These investigations were made to determine, first, the extent of the abuse or misuse of the standard "inclosed" fuse; second, whether the experience with the "refillable" or "renewable" inclosed fuse indicated a decrease in the fire hazard through their use; third, if the operation of the Economy fuse was satisfactory.

Affiant further states that in addition to the special investigations mentioned above, all inspectors of this department have been consulted, and have been instructed to report the results of their inspections regarding the three items mentioned above. The results of these investigations are:

1. That the abuse and misuse of the standard "inclosed" fuse does exist to a great extent and that it is impossible to stop such misuse and abuse.

2. That, as a general proposition, the standard "inclosed" fuse is not safe unless inclosed in a fireproof cabinet.

3. That the item of cost is the greatest factor in the abuse and misuse of the standard "inclosed" fuse, this item of cost being made up of the cost of renewals and the investment in the necessary reserve supplies.

That coming from Mr. Tousley should have great weight, because it will be supplemented with a large amount of other evidence that we have here, and is the most important fundamental thing, after you admit the abuse of the standard fuses, there is involved in this question of fire hazard, because, as he says, the item of cost is the greatest factor in the abuse and misuse of the standard inclosed fuse, this item of cost being made up of the cost of renewals and the investment in necessary reserve supplies; that is, they can not carry enough reserve stock so that the intentional as well as the unintentional overfusing will not creep in. (Reading resumed.)

> 4. That there is a real demand for, and economy in the use of, the refillable fuse manufactured by the Economy Fuse & Manufacturing Co.
> 5. That many large users of fuses attempt to refill standard "inclosed" fuses on the premises without proper equipment or facilities for so doing.
> 6. That the fire hazard as affected by improper fusing is reduced by the use of the refillable fuse as manufactured by the Economy Fuse & Manufacturing Co.
> 7. That the Economy refillable fuse is satisfactory in actual operation and no case of improper refilling has been found.
> We have found no records of fires or hazardous operations with the Economy refillable fuse. We have a number of records of fires from standard "inclosed" fuses which have been improperly refilled or otherwise abused.

That is no reflection on the standard fuse, as a fuse, because it is through the abuse or the misuse of the fuse that it is rendered not a fuse, which makes it the fire hazard. It is no reflection on the manufacturers who are assembled here, respresenting the standard fuses, but goes to our question, because we say we eliminate that to some extent—at least we are no greater. (Reading resumed.)

> Affiant further states that they have in the office of his department, at the present time, many examples of improperly filled standard "inclosed" fuses, and that they have also thrown away or discarded many examples of the same. Those now on hand consist of standard fuses reinforced with heavy copper wire, same type of fuses with iron nails driven through the inclosing tubes, metal tubes of such size as to fit the fuse clips on the cut-out block, solid copper castings to fit the clips on the cut-out blocks, and many examples, some of which are so altered as to require enormous currents to blow them, others so altered as to make their operation extremely hazardous.
> Affiant further states that tests made by or in the presence of representatives of the department indicate that the standard "inclosed" fuse as refilled by the manufacturer or others, who make a business of such refilling, does not act in the same manner as a new standard "inclosed" fuse, and that they often vent fire and disrupt on severe short circuit.
> Affiant further states that the number of inspections made by the department last year was 123 190. There are about 1600 electric plants in charge of the reinspection division, with a number of large installations supplied with current from central stations.
> Affiant further states that a number of fires have occurred in this city as the result of the misuse and abuse of standard "inclosed" fuses. Probably the most serious fire which has been called to his attention occurred about eight years ago. A large alternating current motor in use in the ice plant of Swift & Co. in the Union Stock Yards was overloaded. The cartridge fuses protecting this motor had been altered and a solid piece of steel wire placed through the center of the same in place of the ordinary fusible element.

There was a case of the refilled, not the bridged fuse. (Reading resumed.)

> The result was a setting fire to the motor, which spark communicated to the building and destroyed it and some freight cars, causing a loss which amounted to about $50 000.
> Further affiant saith not.
>
> VICTOR H. TOUSLEY.

There are not very many of these affidavits, and if I may have the opportunity I should like to read them, because reiteration helps the memory and helps us to get the picture. The next affidavit is by William S. Boyd. I might say that both these two, and some of the other affidavits, are from members of the electrical committee of the National Fire Protection Association, and have been given especial consideration on

that account, as this subject was referred by the Laboratories to the electrical committee some two years ago. (Reading.)

William S. Boyd, being first duly sworn, deposes and says that he is located in the city of Chicago, Cook County, Ill., and is and has been for about 20 years almost continuously engaged in the supervision of the installation, operation, and maintenance of electrical wiring and apparatus, for the purpose of preventing loss or damage to property by fire. Of this time 6½ years were devoted to this work in behalf of the Chicago Underwriters' Association in Chicago and Cook County, and the past 11½ years were devoted to this work under the direction of the Committee on Fire Protection Engineering of The Union, an organization of about 90 of the larger fire insurance companies operating in the central western districts of the United States, comprising about 20 States, extending from Pennsylvania to the Rocky Mountains and from Canada to and including Tennessee; that as such electrical inspector he acts in an advisory capacity to insurance companies and various inspection departments in the field above outlined, and the various inspectors consult with him in regard to practices in the use of electrical devices, including inclosed cartridge fuses in industrial and mercantile establishments in the territory named, and on many occasions outside of this territory.

Affiant says that his experience and the experience of the inspectors reporting and consulting with him is that almost invariably in all industrial and mercantile establishments where induction motors are involved or where there is any necessity for the frequent blowing of fuses in the protection of machinery, the abuse of the so-called "standard" or "approved" inclosed cartridge fuses has been observed and is quite prevalent; various means of refilling these "standard" or "approved" so-called nonrefillable fuses being resorted to, some of which are difficult of detection on the part of inspectors, others being apparent, such as soldering copper wire across the terminal caps.

Affiant at the moment does not recall specific instances of fire damage from inclosed fuses, but a number of such instances have been reported to him in the last 11½ years.

Affiant further says that a large number of the readily renewable cartridge inclosed fuses manufactured by the Economy Fuse & Manufacturing Co., of all sizes and types, are in use in various industrial establishments in the territory under his jurisdiction; that he especially sanctioned their use because of his belief that they would reduce the tendency to refill the present so-called "standard" nonrefillable fuses and thus reduce the fire hazard, and that his experience with their use in the last two years has shown his belief to be a fact; that these fuses have been in use in said territory for over two years; that he has yet to discover an instance in which one of the Economy fuses has not been properly refilled and with the element furnished by the maker of the proper rating, and that no improper refilling of the Economy fuses has been reported to him and that the inspectors have been on the lookout for an abuse of the Economy fuse because of the motion of the Underwriters' Laboratories in referring the question of the approval of these fuses as within the National Electrical Code to the electrical committee of the National Fire Protection Association, of which affiant is a member.

Affiant further says that his large experience with "standard" cartridge-inclosed fuses in industrial plants has shown him that a safe renewable inclosed fuse, such as that put out by the Economy Fuse & Manufacturing Co., which is easy of assembly with a cheap renewal element furnished by the maker, enabling a large stock to be carried of all sizes, materially reduces the fire hazard because in a large percentage of the industrial establishments the operation of fuses is more or less frequent when the safety of machinery and the crowding thereof by workmen is considered, and the expense involved in the use of "standard" nonrefillable fuses makes the electricians and employees resort to various practices of refilling, which are in most cases dangerous.

Experience shows that any fuse may be abused and that it is not the fact of capability of abuse but the incentive to abuse which is important, and that this incentive is largely one of cost of replacement.

It has been found that one of the most frequent abuses of the "standard" so-called nonrefillable fuses is to insert copper wire through the fuse, soldering the ends over, or if this is not readily convenient, to solder the copper wire to the terminal caps and so place the fuse in the clips that this will not be noticeable to the inspector.

Affiant further says that in his opinion the practice of permitting the plant electricians to refill "standard" cartridge-inclosed fuses is positively dangerous, even though the attempt be made in good faith to refill properly, because seldom,

if ever, do these electricians use properly designed fuse elements because of lack of knowledge as to the fusible quality and proper dimensions of a proper fusible wire to obtain the rating required.

We have an affidavit from Mr. Sturtevant, as follows (reading):

Albert G. Sturtevant, being first duly sworn, deposes and says he is electrical inspector of the city of Cincinnati, Ohio; that he has had 23 years' experience inspecting electrical installations in said city; that 10 years of this period was spent in the inspection department of the Union Gas & Electric Co.; that 9 years was spent as electrical inspector for the Cincinnati Fire Prevention Bureau; that he has now been in the employ of the city of Cincinnati, in the capacity above stated, for approximately 4 years.

Affiant states that it is the duty of his office to investigate the installation of electric wiring and equipments within the limits of the city of Cincinnati; that he investigates all fires and all accidents which might be attributed to defective wiring in the premises.

Affiant further states that he recognizes thoroughly the fire hazard involved if electrical circuits are not protected with fuses of correct carrying capacity; that, in view of this fact, he has observed closely the condition of such fuses in the circuits of industrial and mercantile establishments.

Affiant further states that his personal investigations develop the fact that a large percentage of the so-called standard nonrefillable fuses were being abused and misused in practice; that he has found on numerous occasions that said nonrenewable fuses have been refilled with elements of unknown capacity; that copper wire, wire nails, fuse wire, and strip are most frequently used by the person in charge of the electrical equipments in refilling said fuses; that he knows without a doubt that such refilling is done on the premises with the elements referred to, greatly increasing the fire hazard.

Affiant further states that for about two years his department has permitted the use of a renewable fuse manufactured by the Economy Fuse & Manufacturing Co.; that this action was taken because he is of the firm opinion that the use of a renewable fuse in large industrial and mercantile establishments, due to the ease and cheapness with which they may be renewed, would materially reduce the danger of overfusing electrical circuits.

Affiant further states that he has observed closely the condition of Economy fuses which were found protecting the circuits in risks in his district; that he has failed to note a case where said fuses have been abused or misused; that the large users of fuses are desirous of obtaining a renewable fuse with a readily renewable element, such as manufactured by the Economy Fuse & Manufacturing Co.; that this demand is because of the fact that it is quite expensive to replace so-called standard nonrenewable fuses when blown; that primarily the demand is an economical one.

Affiant further states that it is very hard at the present time for an electrical inspector to determine whether or not a standard nonrenewable fuse has been refilled on the premises, because of their construction; that an attempt to ascertain the carrying capacity of said fuses would mean that the fuse would have to be destroyed; that with the use of a fuse, such as manufactured by the Economy Fuse & Manufacturing Co., it is possible for the inspector to examine the same and determine whether or not renewal links of the correct current capacity have been used.

We have another affidavit from a man in Indianapolis by the name of Fort H. Moore. (Reading.)

Fort H. Moore, being first duly sworn, deposes and says that he is the chief electrical inspector of the Indianapolis Inspection Bureau and electric wire inspector for the city of Indianapolis in the city of Indianapolis, Marion County, Ind.; that he has been in the service of the Indianapolis Inspection Bureau for a period of 11 years, as follows: Two years as field inspector of interior wiring and 9 years as chief inspector; that the Indianapolis Inspection Bureau, of which he is chief inspector, has jurisdiction over all interior wiring within the limits of the city of Indianapolis and Marion County, Ind.

Affiant further states that he supervises the installation and maintenance of all electric wires and apparatus in the city of Indianapolis, being appointed by the Board of Public Safety and working in conjunction with the department of buildings of said city.

Affiant further states that there are four inspectors employed by the Indianapolis Inspection Bureau and working under his direction. Their duties are to inves-

tigate fires due to the improper installation of electric wiring or equipment and to inspect such equipments when they are originally installed.

Affiant further states that he has instructed inspectors to observe closely the fusing of all electrical circuits; that said inspectors have reported to him on numerous occasions that they have found the abuse of so-called standard nonrefillable fuses and that such fuses were usually refilled with fuse wire or strip of greater capacity or the use of copper wire or some other element which did not provide adequate protection.

Affiant further states that the item of cost is the greatest factor in the abuse and misuse of standard nonrefillable fuses, and this item of cost being made up by the cost of renewals and the investment in the necessary reserve supply, that many large users of fuses attempt to refill such standard nonrefillable fuses on the premises without proper equipment or facilities for so doing; that the fire hazard as affected by improper fusing is very great, and that the practice of refilling such standard nonrefillable fuses by the plant electrician is positively dangerous.

Affiant further states that there is a constantly increasing demand for refillable fuses, such as manufactured by the Economy Fuse & Manufacturing Co., and that he is firmly convinced that the use of such fuses in industrial and mercantile establishments will materially reduce the fire hazard due to the nominal cost at which the Economy Fuse & Manufacturing Co. furnish renewal links for use in their fuses. That such renewal links are stamped with their rated capacity in amperes and voltage, and are of known value, and that such renewal links may be inserted in said fuses very easily and quickly.

Affiant further states that his inspectors have never reported to him the improper refilling of such fuses in his personal investigations and that his experience has shown that said fuses always operate satisfactorily.

We have an affidavit from Charles H. Trame, who says (reading):

Charles H. Trame, being first duly sworn, deposes and says that he is branch manager of the Kentucky Actuarial Bureau, Covington, Ky., and has been in the service of said bureau for 20 years, as follows: Twenty years as general inspector and 7 years of the 20 referred to as electrical inspector in connection with other investigations and inspections.

Affiant further states that his department has jurisdiction over the installation of electrical wiring and equipments in the counties of Kenton and Campbell, Ky.; that as such electrical inspector he examines the installation of all interior wiring; that he investigates all fires and accidents which may be reported as having been caused by defective electrical wiring or other sources.

Affiant further advises that in the course of his inspections that the question of fuse protection is given careful attention, and that the abuse of the so-called standard nonrefillable fuses is so general with all kinds and sizes of conductors that nonrefillable fuses, instead of being a protection against the overloading of wires, have really developed into a menace and a fire producer, and the general condition of fuse protections is found to be such that it is apparent to all engaged in the business of electricity that some means must be found to overcome this misuse of fuse protection.

Affiant further advises that he has recommended the use of the renewable fuse, the product of the Economy Fuse & Manufacturing Co., for a period of several years, and that he is firmly of the opinion that said fuses have lessened the fire hazard in all classes of property, as the Economy Fuse & Manufacturing Co. furnish the patrons of their product with renewable links plainly stamped with their ampere capacity at a reasonable cost; fuses manufactured by the said company can be and are easily and quickly refilled and replaced by the person using same.

Affiant further states that it is possible for the inspector to examine said fuses manufactured by the Economy Fuse & Manufacturing Co. and ascertain if the proper renewal element has been used; that this is a great advantage over standard nonrenewable fuses which may be refilled on the premises without detection, because it is not possible for the inspector to dismantle the fuse to observe its construction and contents, without destruction of the fuse.

Affiant further reports that never at any time has he in his personal investigations discovered a location where the operation of the Economy renewable fuses has in any way proved hazardous or not given satisfaction.

Affiant further states that there are very good reasons why there is a crying demand for a renewable fuse, such as produced by the Economy Fuse & Manufacturing Co.; all users of fuses, both in a large and a small way, complain that the present cost of replacing standard nonrefillable fuses is expensive, and that it

becomes a necessity due to this cause and the trouble of sending out for new fuses, to resort to the practice of renewing the old fuses as best they can, and while the patched-up or strapped-over fuses are in many cases only to be a temporary matter, it is a fact, however, that in most all cases that they remain a permanent factor, and their existence, unfortunately, in a great many cases, is never again thought of until a fire occurs. It is the opinion of the affiant that the possibility of being able to secure a fuse of the Economy type does and will continue to prevent fires from the cause mentioned above.

We have an affidavit from Edward W. P. Smith, who deposes and says. (Reading.)

That he is the city electrician of the city of Cleveland, Cuyahoga County, Ohio; that he has been in the service of said city in the capacity named for a period of 15 months; that the department has jurisdiction over all interior wiring within the limits of the city of Cleveland.

Affiant states that there are nine inspectors assigned to his department to investigate the condition of electrical installation; that said inspectors investigate all fires and accidents when defective wiring or electrical equipment is reported as the cause.

Affiant further states that his inspectors in the field have informed him of places in which standard so-called nonrenewable fuses have been abused and misused; that such abuse usually consisted of a jumper of steel wire or copper wire, either placed on the inside or the outside of the fuse; that this was not always done purposely to increase the carrying capacity of the fuse, but was done in good faith, assuming that they were providing adequate protection to the electric equipment and property.

Affiant further states that the use of such copper wire and other metals of unknown carrying capacity, when used in the manner above referred to, is very dangerous from a fire hazard.

Affiant further states that he is firmly convinced that the use of a renewable fuse, having satisfactory performance characteristics and of rugged and careful construction, would, when placed in use in large industrial and mercantile establishments, materially lessen the fire hazard, because of the ease and quickness with which such a fuse could be renewed and the fact that renewal elements of a definite and known capacity are furnished by the manufacturer for use in such fuses.

I will next read the affidavit of Howard M. Maxwell. (Reading.)

Howard M. Maxwell, being first duly sworn, deposes and says that he is electrical inspector of the Ohio Inspection Bureau; that he has been in the service of said bureau for a period of nine years; that the department investigates the installation of all interior wiring in the southwestern part of Ohio.

Affiant states that there are two inspectors assigned to investigate the condition of electrical wiring in large industrial and mercantile establishments in their districts; that they investigate all accidents and fires originating from defective wiring.

Affiant further states that he has instructed his inspectors to examine carefully fuses protecting electrical circuits because he is aware of the danger to electrical equipments and property if such circuits are not adequately protected; that on numerous occasions it has been reported to him by said inspectors that so-called nonrenewable fuses have been abused and misused; that is to say, that they have been renewed on the premises with copper or lead fuse wire and strip of unknown capacities and various other means have been resorted to; that in his own personal investigations he has found similar conditions existing.

Affiant further states that the usual reason given for the abuse and misuse of such standard nonrenewable fuses is the great cost of replacing such fuses when blown; that in large industrial plants where the machinery is crowded by workmen fuses are blown frequently; that this is an item of great expense and the practice of renewing such fuses, although it is done in good faith with elements of supposedly proper carrying capacity, is a distinct fire hazard.

Affiant further states that he has permitted risks under his jurisdiction to use the renewable fuse manufactured by the Economy Fuse & Manufacturing Co.; that his inspectors, although they have examined closely such fuses after having been renewed in service, have never reported to him a case where an element of greater carrying capacity has been used; that in his own personal investigations he has always found said fuses renewed with elements of proper carrying capacity, and that the performance of said fuses has always been satisfactory.

Affiant further states that a number of concerns who find occasion to frequently replace blown-out fuses have requested permission to use the renewable fuse as put out by the Economy Fuse & Manufacturing Co., and that there is an increasing demand in his territory for such renewable fuses; that he believes the use of such renewable fuse will materially lessen the fire hazard because of the ease and quickness with which said fuses may be renewed on the premises in a satisfactory manner with an element of definite and known capacity which is furnished by the said Economy Fuse & Manufacturing Co. at a very nominal cost.

Affiant further states that he has found it very difficult to detect standard nonrenewable fuses when they have been refilled on the premises; that it is a very simple matter to examine the construction of said Economy fuses without destroying the fuse; that they are therefore in a position to know whether or not the fusing of electrical circuits is done in a proper manner when said Economy fuses are used.

I will next read the affidavit of William B. Hubbell. (Reading.)

William B. Hubbell, being first duly sworn, deposes and says that he is the chief electrical inspector of the Cincinnati Fire Prevention Bureau and has been in the service of said bureau for 14 years, as follows: Three years inspector of interior wiring and 11 years as chief inspector.

Affiant further states that the department has jurisdiction over all interior wiring within the limits of the County of Hamilton, Ohio.

Affiant further states that there are eight inspectors assigned as follows: Four assigned exclusively to the investigation of the installation of electrical wiring and equipments, and four general inspectors who investigate the conditions of electrical installations in connection with their other work.

Affiant further states that he has issued instructions to his electrical inspectors, stating that they must observe very closely that electrical circuits are protected with fuses of the correct capacity; that said inspectors have advised him many times of the abuse and misuse of so-called standard nonrefillable fuses; that generally it was observed that the electrician who was responsible for the refilling of such fuses on the premises had used copper wire, wire nails, fusible wire of unknown capacity and rating, and other materials, thus introducing a great fire hazard.

Affiant further states that he has permitted the use of a renewable fuse manufactured by the Economy Fuse & Manufacturing Co. for a period of two years, and it is his firm opinion that the use of said renewable fuses in industrial and mercantile establishments lessens the fire hazard to a very great degree, because the Economy Fuse & Manufacturing Co. furnish the users of their fuses renewal links plainly stamped with their ampere capacity at a very nominal cost; fuses manufactured by the Economy Fuse & Manufacturing Co. can be easily and quickly replaced by the user.

Affiant further states that it is possible for the inspector to examine said fuses manufactured by the Economy Fuse & Manufacturing Co. and ascertain if the proper renewal element has been used; that this is a great advantage over standard nonrenewable fuses which may be refilled on the premises without detection, because it is not possible for the inspector to dismantle the fuse to observe its construction and contents without destruction of the fuse.

Affiant further states that his inspectors have never brought to his attention, nor has he in his personal investigations discovered a case where the operation of Economy renewable fuses has been hazardous or unsatisfactory.

Affiant further states that there is, for economical reasons, an increasing demand to use a renewable fuse, such as manufactured by the Economy Fuse & Manufacturing Co.; that the large users of fuses contend that the present cost of replacing standard nonrefillable fuses when blown out is very expensive; that it becomes necessary, due to this great cost, to resort to the practice of renewing said standard nonrefillable fuses on their own premises; that when such refilling is done on the premises, improper materials are used; that such refilling of standard nonrefillable fuses affords no protection to the electrical equipments and property, and therefore becomes hazardous.

The next affidavit is that of Harvey E. Bloomer, which I will read. (Reading.)

Harvey E. Bloomer, being first duly sworn, deposes and says that he is the chief electrical inspector of the Wisconsin Inspection Bureau, an institution maintained by over 125 fire insurance companies for the purpose of making rates and the supervision of installation, operation, and maintenance of electrical wiring

and machinery to minimize the fire waste; that said bureau has been in operation since about January 1, 1915, and that the jurisdiction of the Wisconsin Inspection Bureau covers the entire State of Wisconsin, including the city of Milwaukee; that just previous to his connection with the Wisconsin Inspection Bureau he occupied, for a period of 12 years, a similar position with the Milwaukee Board of Fire Underwriters in full charge of electrical inspection.

Affiant further states that inspections made in the territory above mentioned (the State of Wisconsin) include all electrical installations for power, heat, and light in the interiors of buildings and also pole-line construction and wiring where same runs close to or enters any building covered by insurance; that in all such installations of electrical wiring, as a general practice, cartridge-inclosed fuses are used in large quantities.

Affiant further states that in the inspection of all electrical wiring and equipment he gives particular attention to the protective devices, which include, in most installations, cartridge-inclosed fuses of the types generally used and known as "standard" or nonrefillable fuses, constitutes a great fire hazard when not properly used and also because of the prevailing practice of overfusing circuits in order to minimize the operation of fuses and thus to reduce the maintenance cost of such fuses; or, to refill or bridge across such "standard" or nonrefillable fuses with copper wire, lead wire, solders, and various other methods in order to prevent the frequent blowing of fuses in service; all of which practices result in the introduction of a distinct and very grave fire hazard.

Affiant further states that he has always believed that such hazardous practices would not exist if the cost of providing adequate fuse protection were reduced to a nominal sum, and has, therefore, continuously permitted, for over two years, the use of the renewable fuse made by the Economy Fuse & Manufacturing Co., which can be renewed in a proper manner, with elements made and furnished for the purpose by the Economy Fuse & Manufacturing Co. at a very trifling cost. These Economy fuses have been inspected very critically for the entire period since their use was authorized by affiant, and great numbers of them have been opened in order to observe whether or not they were at all times properly refilled with Economy renewal elements of the correct capacity to protect the circuit in which the fuses were used.

Affiant further states that in all his inspections and experience the fuses made by the Economy Fuse & Manufacturing Co. were promptly refilled and that no substitute articles or fusible elements or Economy elements of too great capacity have been found; that in questioning the users, the invariable answer was that the Economy fuse is giving perfect satisfaction and that it is being renewed in a proper manner because of the rapidity of the work and the ease of insertion of fuse elements, and also because of the cheapness of the Economy elements and the very small investment for large stocks of same, making large reserve stocks instantly available for emergency demands.

Affiant further states that where "standard" or nonrenewable fuses are used, and the user returns same after operation to the factory of the original maker, or to others outside of the users' premises, for factory refilling, that the nonrefillable fuse, as refilled by the maker or others in such factories, is not as satisfactory in operation as the original new fuse because of apparent careless workmanship and by damage to mechanical parts and especially the terminals and from lack of uniform work in replacing the filling material, or of the filling material sifting out of end holes or between caps and tube during transportation and handling in the plant of the user.

Affiant further states that large numbers of users have stated to him that they prefer to use the Economy fuse instead of "standard" or nonrefillable fuses because of the better service they have obtained from them and because Economy fuses are easier and cheaper to refill than nonrefillable fuses which they had previously made a practice of refilling on their own premises but for which they were unable to obtain the necessary materials from the maker and which resulted in frequent burnouts of motors and other appliances; that the use of the Economy fuse has eliminated the dangerous practice of improper re-fusing of circuits and the frequent burn outs of motors and other appliances.

Affiant further states that several cases have come to his attention where nonrefillable fuses have operated with violent explosions or where such fuses become so hot in service that the fuse tube is weakened and brittle from burning or charring and that many of these nonrefillable fuses are incapable of being refilled even by the original maker and that in those same cases Economy fuses have since been used and have given highly satisfactory service, after having been renewed several times, and no damage to any parts has been detected on close inspection and examination.

We have not an affidavit here from the inspection department of the middle department of Philadelphia, which is quite extensive, but that department has furnished us with some interesting data of which I have a copy here, and which can be checked up and probably has been checked by the Bureau. They adopted the same plan in order to ascertain this fact as to the use of the Economy fuse, as to whether it was being properly refilled, as to whether it was lessening or decreasing the percentage of fusing, and they sent out a list of six or seven questions to 530 users of fuses in their territory, and they got back 306 replies. Of those replies, 256 answered that they were still using the Economy fuse. The remainder did not answer or were not using them. Eleven stated: "Removed because of objections from insurance or inspection departments"; 3 stated "prefer other fuses and have replaced them"; 1 replied "replaced with circuit breakers"; 1 replied "we let out maintenance of our motors on contracts and the contractor substituted standard fuses"; and 1 said that he was replacing them and had only those on hand. They were asked: "Has their operation been uniform both as to current ratings and the opening of circuits in practical service?" Two hundred and sixty-one replied "yes"; 4 said "no"; 1 said "we have found from tests at various times that a 10-ampere fuse blows at 13 amperes and a 3-ampere fuse at 5 amperes"; 1 said "they vary about 4 amperes lower"; 1 said "the majority open too soon, due to being punched by square shoulder under notch. It may have been that they did not know what the rating was. Thirty-eight made no reply specifically.

The next question was: "Have any undesirable features developed differing from other types of inclosed fuses; if so, in what respect?" Two hundred and forty out of 306 replied "none." Then there were a number of specific answers. One said "the only trouble is due to the stripping of thread when screwed up too tight, which either destroyed the cartridge or leaves a loose connection. This only applies to small sizes." That is the old-style ferrule type which was discarded and as to which we have had a number of complaints. One said "extreme care must be used in refilling." One objected that "they require intelligent handling in replacing, as if asbestos cover is not put on they are dangerous." These particular answers have all been checked up and found to be from users of our old-style filling material or of the asbestos sheathing.

Question 4 was: "From your experience have you concluded that these fuses possess sufficient merit to warrant recognizing them as standard and so listing them?" Two hundred and fifty replied "yes"; 5 replied some in one size and some in another, and some offered objections, but 45 did not reply.

Question 5 was: "Do those in charge of your fuses replace blown elements with those of the proper size and ratings required for the shells?" Two hundred and sixty replied "yes"; 41 did not answer, and 5 others replied as follows: One, "until provided against, fuses were occasionally double filled where trouble due to overload developed"; that is, they put two links into one shell, which will sometimes happen where trouble was due to an overload. Another one stated that "they do, unless for some special reason it is necessary to do otherwise." As I stated before, we can not stop intentional overfusing.

Another one says "most always," and another one "can not tell without taking apart and examining." So that the great percentage, you see, do properly refill—4 out of 260 do not. I think there were all but about 5 who replied that the fuses were at all times properly refilled, and others gave sufficient reasons or wanted for some special purpose a higher amperage.

Also on this question of the abuse of the approved fuse, we submitted evidence and on the questions of the reasons for it, what I think is some evidence, and that is the statement contained in the application of Robert C. Cole, who is an employee of one of the largest fuse manufacturers on patents assigned to them as to why he considered

his invention, to which he sought the patent, to constitute an invention; that is, an improvement in the art. That patent reference is 1 114 340, and he says (reading)—

> Electric fuses are essentially intended to be safety devices. They are designed to be placed in circuits and to open on an abnormal rise of current and thus protect apparatus connected with the circuits and objects adjacent to the circuits and the fuses. If they do not blow when the conditions become dangerous, they are not safety devices. Much thought and study have been given and much labor and expense has been incurred in order to devise fuses that will blow accurately under the predetermined conditions and thus be dependable safety means. It is required that the fusible element be inclosed in order to eliminate the dangers of the opening of the circuits when the fusible elements melt. Fusible elements that are inclosed can not be seen. To save expense, unscrupulous persons and those not skilled in the art frequently, after a fuse has blown, insert a new fusible element in place of the one that has been destroyed. As a result, it often happens that fusible elements of a capacity not warranted by the conditions have been placed in fuses and because the elements could not [have] been seen these have been passed as safety devices, on the assumption that the elements were of the proper capacity and of the rating stated on the fuses, whereas, as a matter of fact, the fusible elements were of so much greater capacity that the fuses instead of being safety devices were an element of danger.

Then he goes on to say that the object of this device is to so construct an inclosed fuse that after the fusible element originally placed therein has been disrupted or destroyed the structure can not be disassembled or manipulated in such a manner that another fusible element can be placed in the interior. In other words, the argument I make from this is that here is an admission right from the manufacturers of approved fuses that all the fuses are refillable. It is here stated right in their own patent application as the reason why they considered the nonrefillable fuse an advance in the art.

Then we have an affidavit from Walter E. Flickinger, who says (reading)—

> That he is the engineer of the Michigan Inspection Bureau located in the city of Detroit, County of Wayne, Mich.; that he has been in the service of said bureau for a period of five years; that his department has jurisdiction over all interior wiring within the State of Michigan.
>
> Affiant states that there are four inspectors whose duty it is to investigate the condition of electrical wiring and electrical equipments within the territory referred to above; that they investigate accidents and fires which might be reported to them as having been caused by electrical defects.
>
> Affiant further states that he has instructed said electrical inspectors to notice carefully the condition of fuses protecting electrical circuits; that said inspectors have advised him that they have found so-called standard nonrefillable fuses abused in service; that said abuse usually consisted of bridging the terminals either on the interior or the exterior of the fuse with copper wire, steel wire, nails, and lead and fuse strip of unknown capacity and rating; that such practices were a distinct fire hazard.
>
> Affiant further states that the item of cost in replacing so-called standard nonrefillable fuses is responsible in some measure for the abuse of the device in service; that to reduce fuse maintenance expense the hazardous practice of refilling standard fuses with elements of greater carrying capacity is resorted to.
>
> Affiant further states that he is of the opinion that the renewable fuse as manufactured by the Economy Fuse & Manufacturing Co. might reduce the fire hazard because of the ease and quickness with which said fuses can be properly refilled with an element of known capacity.
>
> Affiant further states that his inspectors have never reported to him that the fuses now put out by the Economy Fuse & Manufacturing Co. have been improperly refilled on the premises; that in his own personal investigations he has never observed the improper refilling of said fuses and that his experience has shown that said fuses always operate satisfactorily when properly refilled.

I also want to refer, because it is getting near the closing hour of 12.30, to a statement made by Mr. Merrill on the question of the use of refillable fuses, which I think is entitled to very considerable weight. This is one of the things he was investigating at the time when this refillable fuse question, as a question, was more or less new. At that time, on account of the wording of the National Electrical Code under which

the Laboratories make their tests and with the requirements of which we claim that our fuse complied, of course Mr. Merrill thought it very proper to state whether or not our fuse complied with the code, and in his report he makes some observations on this practice of improper refilling, and what he considered to be the desirable part and use of refillable fuses, which I think will be of interest. His observations were as follows. (Reading.)

> The design of these fuses and the ease with which they may be renewed with proper elements supplied by the manufacturer, lessen to an appreciable extent the likelihood that improper fuse elements will be employed in them.
>
> Information obtained from insurance and municipal inspection departments and from listed manufacturers of cartridge-inclosed fuses, all indicate that the practice of renewing or refilling fuses by the users is on the increase and that a growing demand is being made on the manufacturers for fuse elements and parts to carry on this work. In some instances the manufacturers have supplied parts of fuses for this purpose.
>
> Since, from such reports as are obtainable, it would appear that the practice of renewing or refilling fuses by users is increasing, it would appear proper to give careful consideration to a form of fuse which, if properly used, may tend to reduce the bad results which must be anticipated from any attempt to refill standard cartridge fuses which are not designed for such service, except when refilled by the original manufacturer.
>
> The practice of rebuilding fuses and substituting homemade and dangerous fusible elements on the part of users and others than the original manufacturers, usually results in inadequate protection against overloading of the circuits of which the fuses are a part, if not the introduction of a distinct and additional fire hazard.
>
> Standard cartridge-inclosed fuses of the present types are intentionally constructed to be difficult of renewal and the consequent cost of rebuilding is so high that a great inducement exists for the user to keep circuits in commission by patching up fuses with lead alloy or copper wire, or by any other means that may suggest itself. The manufacturers do not supply fuse parts as a matter of regular business.
>
> Which, of course, makes the cost of reassembling of fuse absolutely prohibitive; even though it may be more or less easy of reassembling they have not the parts to put in.
>
> And even if the elements could be purchased it is quite certain that the rebuilt fuses would be of uncertain quality and safety, owing to the complicated construction of the devices, the somewhat delicate relations to be observed in assembling these fuses and the probability that certain parts may have been injured or lost in doing the work.
>
> From all available sources the evidence upon the renewing of cartridge-inclosed fuses is such that the Laboratories are of the opinion that a well-designed and constructed renewable fuse having simple parts and low-priced fusible elements should, on satisfactory performance, be considered with favor as tending to replace improper and dangerous substitutes and discouraging the activities of incompetent persons in work of this nature.

I have just two more statements from men of experience in the actual investigation of fuses. The next is from James H. Fenton. (Reading.)

> James H. Fenton, being duly sworn, deposes and says that he is located in the city of St. Louis, State of Missouri, and is the electrical engineer for the St. Louis Fire Prevention Bureau, an insurance organization for the inspection and improvement of buildings insured by a large number of insurance companies. His duties are inspecting and advising upon safe methods for electric wiring and appliances for light, heat, and power inside of buildings. He has been engaged in this work almost continuously for 25 years.
>
> Affiant says in connection with this work that the abuse of the fuse element used for protection of electric light, heat, and power wiring is a source of great danger, principally from what is known as overfusing and destroying the protection afforded by the proper fuse element.
>
> Affiant believes if a proper renewable fuse can be furnished with a standard rated capacity it would greatly lessen the danger from fires caused by electric wiring and prevent the user from refilling or jumping the fuse with copper wire, etc. It is an opinion of all inspectors connected with the office that a fuse element that can be examined is preferred to one that is not accessible, and if

a fuse that could be easily renewed could be approved, it would be helpful in relieving the practice of overfusing.

Affiant further states that in order to obtain definite knowledge of the use of renewable fuses in his territory a personal examination was made of a number of installations in which the aforesaid fuses are installed and he found that they had given entire satisfaction to users and are a great help to inspectors in determining whether the fuse element is of proper rated capacity to safely protect the wire or device installed.

I might say that Mr. Fenton would not give us any statement until he had taken two or three weeks' time after our request was made to make this personal investigation of his own, and he sent us that statement.

The next is from Fred G. Waldenfels, who said. (Reading.)

Fred G. Waldenfels, being first duly sworn, deposes and says that he is located in the city of Chicago, Cook County, Ill., and is and has been for the past eight years continuously engaged in the supervision of installation, operation, and maintenance of electrical wiring and apparatus as chief electrical inspector for the Chicago Board of Underwriters; that as such the electrical inspector acts in an advisory capacity to the insurance companies constituting the Chicago Board of Fire Underwriters; that the jurisdiction of said board covers all electrical wiring and apparatus within Cook County, and that frequently he consults with insurance companies in regard to the electrical wiring and apparatus for points outside of the above-mentioned territory.

Affiant further says that he inspects annually approximately 2,500 buildings and that because of his knowledge of the fire hazard resulting in the misuse of inclosed cartridge fuses, he gives particular attention to the examination and inspection of electrical protective devices, which includes cartridge-inclosed fuses.

Affiant further states that about two years ago the Chicago Board of Underwriters issued general instructions permitting the use of Economy renewable fuses in installations under its jurisdiction, in order to obtain actual service experience in the operation and maintenance of same, and because of this permission to use he has given special attention in his investigation to Economy fuses in various classes of buildings and service.

Affiant has also questioned a large number of users of Economy fuses, and the users, almost without exception, report that said fuses are giving excellent satisfaction; that they are almost invariably refilled in a proper manner with the renewal element of the proper capacity to protect the wires or devices, and that the user generally has a large stock of Economy element on hand for emergency service. These reports from the users are confirmed by investigations made by this affiant and his investigation has shown that much greater stocks of fuses in renewal elements are carried on hand because of the small investment involved than are carried of standard fuses when the so-called nonrenewable or standard fuses are used. Affiant says that he has discovered only one or two cases of improper renewals of Economy fuses, which shows very marked decrease in the abuse of fuses.

Affiant further states that the so-called nonrenewable or "standard" fuse is very generally abused, in many cases for the reason that the user considers the cost of replacing a blown fuse with a new one exorbitant. In many cases a deliberate attempt to overfuse the circuit by bridging the circuit either across fuse terminals or within the cartridge fuse has been found.

Affiant further states that he receives daily reports of all fires in the city of Chicago as issued by the Chicago Fire Insurance Patrol, and that he inspects all premises after fires which have been reported by the Chicago Fire Insurance Patrol as having been caused by defects in the electrical wiring or apparatus, or otherwise known as "electrical fires." In the fires reported in this manner, investigation shows that a large number of same have been caused by the operation or lack of operation of so-called nonrenewable or "standard" fuses which had been improperly refilled or bridged, but in the experience of affiant no fire has been found to be caused by the use of Economy renewable fuses. Many fires of electrical origin reported by the Chicago Fire Insurance Patrol as defective motors, etc., can be traced to the operation of so-called "standard" cartridge fuses which have been improperly refilled by the user with such materials as copper wire, nails, lead fuse wire, of incorrect capacity, etc., and a large number of investigations prove the cause to be the use of jumpers across the fuse termi-

nals. The most recent investigation made was that of a fire which occurred on May 17, 1915, in the pent house of a hotel at 66–72 West Randolph Street, Chicago, this fire having been reported as caused by a defective elevator motor. Upon investigation it was found that a pump circuit was tapped from the elevator motor circuit and the fuses used in the pump circuit were each bridged with No. 14 copper wire. One fuse was totally destroyed, and the other was in a very badly damaged condition, but in each cut-out clips the copper jumpers were intact; the one fuse and two copper jumpers referred to were removed by affiant and are submitted herewith and marked Exhibit No. 1.

Affiant further states that his experience indicates a general public demand for the use of a practically designed renewable fuse, such as is made by the Economy Fuse & Manufacturing Co., and that the cause for this demand on the part of the user is because of the general desire to reduce operating expenses, which expense for cartridge fuses is a considerable item in plant maintenance, and that affiant, as well as the users who formerly preferred the use of open-link fuses in fireproof cabinets, now prefer Economy fuses to the so-called nonrenewable or "standard" fuses in such installations.

Then we have a letter from Mr. Sellers, of Columbus, Ohio, who is also a member of the electrical committee, I think, addressed to our company. (Reading.)

We have your favor of the 22d instant inclosing affidavits made by a number of electrical inspectors regarding their experience with cartridge-inclosed fuses, both of the standard approved nonrenewable types and also renewable fuses of the Economy type.

You request that we advise you as to the experience this bureau has had in this field with the above types of fuses, and replying thereto we wish to state that while our data can not be considered complete, yet our records do not show that any serious results have been occasioned by the misuse of improper elements being inserted in either of these types of fuses.

In our territory in this immediate vicinity the renewable fuses of the Economy type are not generally carried in stock by the jobbers, and therefore our experience with same has been more or less limited.

As requested, we are returning herewith the papers which you sent us.

Then we have a letter from the Cleveland Inspection Bureau, of which C. H. Patton, whom I think is well known to this Bureau, is the head, and he countersigned the letter. (Reading.)

The undersigned herein offers his views as regard installation of the above-named type of fuses, viz:

(1) Inclosed fuses of all makes have been found to be badly abused.

(2) The refillable type is of no more hazard than that of the nonrefillable type.

(3) That either types when properly installed according to code, and not abused, are considered equivalent to standard approved by this office.

I understand you wish to take a recess at 12.30. That finishes one part of the argument.

Dr. STRATTON. Owing to the fact that our luncheon hour was set for half past 12, we shall now take a recess of an hour.

(Thereupon, at 12.36 o'clock p. m., the conference recessed for one hour.)

At the expiration of the recess the hearing was resumed.

Dr. ROSA. Dr. Stratton will not be here this afternoon. We have the names of Mr. Cunningham, representing the D. & W. Co. and the Chase-Shawmut Co.; Mr. Sargent, of the General Electric Co.; Mr. Skinner, of the Westinghouse Co.; Mr. Bates, of the Bryant Electrical Co.; and Mr. Daum, of the A. F. Daum Co. We assume these gentlemen will have something to say in the discussion this afternoon, and if there are others that would like to speak on either side of this question we would like to have their names handed in so that we can call upon them.

Mr. Foote, representing the Economy company, will have an opportunity to add anything he may desire to the argument he made this morning after the others have been heard. We will first hear Mr. Merrill, of the Underwriters' Laboratories.

FURTHER STATEMENT BY W. H. MERRILL

Mr. MERRILL. Mr. Director and members of the staff, I think it is important in the consideration of this question that we should have clearly in mind exactly what we are talking about when we refer to the Economy fuse. The record shows that this company entered the fuse business some time during the summer of 1912, and very properly and very naturally looked into the state of the art as it then was and decided on the use of a powdered filler as an essential element in inclosed-fuse construction. The powdered filler was what originally made the inclosed fuse possible. There were all sorts of attempts in the old days to surround a fuse element in some way so as to prevent a disruptive discharge. It is not necessary to review history to show that various forms of sleeves, binders, and tubes were used, but it is a well-known fact that until the powdered filler came into vogue, until that invention was brought into the market, no form of inclosed fuse, so far as I am aware, gave a successful service record.

Now, bear in mind that this manufacturer utilized the powdered filler in his device up to the latter part of 1913. Our records on file with you indicate that his application to us for a change was made a short while before January, 1914; that is, he put on the market, as was brought out by Mr. Foote this morning, a great many thousand fuses utilizing the powdered filler, and this was two or more years ago.

Owing to the necessities of his business (the reasons need not necessarily have a bearing on this question) he abandoned the use of the powdered filler and looked about for a substitute, and about the latter part of 1913 called to our notice, and in the early part of January, 1914, adopted, the use of an asbestos sleeve over the fuse element, with what he termed a "shredded asbestos end packing," indicating that while he was prevented from using the standard form of filler he still felt at that time that some form of filler was necessary. That is, then, Economy fuse No. 2, Economy fuse No. 1 being the one with the powdered filler, and Economy fuse No. 2 being the one with the shredded asbestos packing and the asbestos sleeve around the fuse element.

I do not understand that the manufacturer contends that the shredded asbestos fuse was in any way successful. While he put several thousand of them on the market, I do not understand that he feels it performed well under experimental laboratory conditions, or that it was a successful fuse in service. I think the record of the tests indicates that the shredded asbestos fuse was objectionable, and I think our Laboratories' record stands as criticizing that form of construction, and so far as I know no objection has been made to our statements in reference to Economy fuse No. 2.

He then turned his attention to overcoming the defects in Economy fuse No. 2 without going back to the very nearly standard form of construction, utilizing the powdered filler which he had been shown in Economy fuse No. 1. That matter was called to our attention some time about June, 1914, when he brought out Economy fuse No. 3.

Economy fuse No. 3, as shown, had no form of filler. It utilized as a distinctive feature the notched-fuse element, and, as I understand it, it depends for its successful operation on a slow form of relief of the pressure generated by the disruptive discharge occasioned when the fuse blows. That fuse has continued on the market since about June, 1914.

At some time within the past two months, I think it will appear, further changes were made in the design, not important radical changes such as differentiate Economy fuse No. 1 from No. 2 and such as differentiate No. 3 from either No. 1 or No. 2, but changes which may or may not be important. The data are not at hand as yet to indicate the importance of these changes, but we surmise that many of them are relatively unimportant. A review covering the details of construction of fuses received from the manufacturer within the last month, as compared with those of the latest type described as Economy fuse No. 1, No. 2, and No. 3, shows the most essential difference consists in the use of brass end washers in the unfillable type, as compared with the phosphor-bronze washers as last submitted. These washers are one thirty-second inch in thick-

ness in fuses of 200 amperes capacity and have as backing two leather washers. In the two samples that we compared the notched brass plates forming the inclosures at the end of the fuse were 0.029 inch in thickness in the old sample and 0.097 inch in the new sample, and the turn caps in the new sample were found to be 1 inch in length and twenty-nine thirty-seconds inch in length in the old sample. In the new sample of 100 amperes capacity, 250 volts, the end brass plate was found to be 0.062 inch in thickness, and 0.067 inch in the old, and the turn cap one-half inch in the new and seven-sixteenths inch in the old sample. In the 300-ampere, 250-volt samples, no changes whatever could be observed.

It is appreciated that, aside from the changes in materials of the end washers, the differences in dimensions are slight and of general inconsequence, and it is also appreciated that the figures are based upon individual samples and do not necessarily represent an average. And we do not contend that these very recent changes, so far as our records are concerned, are perhaps sufficient to designate the June, 1915, Economy fuse as Economy fuse No. 4, but they certainly show added evidence of an instability in design and construction details of this device.

The point I wish to emphasize very particularly, and that I think has a very vital bearing on everything Mr. Foote has presented here, almost without exception, is the essential difference in the device that he made when he abandoned the use of the powdered filler and the further very essential, comparatively recent, and very radical change in the appliance which is in the Economy fuse to-day. All of this evidence from customers and users, all these affidavits from inspectors, of which I wish to speak specifically a little later, I notice cover periods of two years ago. Mr. Tousley's affidavit that was read specifically stated that two years ago he started this investigation; Mr. Hubbell specifically mentioned two years ago; Mr. Waldenfels specifically mentioned two years ago, showing very clearly that it was the powdered-filler fuse that they were investigating and not the fuse that is before this board for investigation and report under the agreement between this manufacturer and Underwriters' Laboratories.

It is more or less common in all manufacturing enterprises to change models, and it is always more or less common to use the same trade name as applying to several different styles of articles, but it is very confusing. I know of nothing in our business that causes more intricacies in our records, more trouble in seeking to give correct advices, than to keep track sometimes of the various articles that are put out under a single trade name and which vary in design, construction, and performance. It is quite common among a number of owners or experimenters that enter into a business because it seems attractive, and not because they have had any particular experience in it, to choose a good trade name and then go ahead and experiment with different appliances under it—"Eurekas," "Excelsiors"; those things are quite common.

I remember an acetylene gas manufacturer who came into my office not so very long ago with his arm in a sling and a bandage about his head. He said, "I am the manufacturer of an acetylene-gas machine, and my machine is perfectly safe." I said, "Were you in a railway accident, or have you been experimenting with high explosives or something?" "No," he said, "that was the machine that I made before I made this one that caused the trouble, but the one I make now is perfectly safe." I said, "What is the name of the machine?" He said, "We call them both the 'Eureka'."

It seems to me that Brother Foote is a little bit turned around so far as the affidavits go, on the same basis. He started in to make a pretty good fuse, and he has got a lot of evidence that shows he made a pretty good fuse; he has got a lot of laboratory tests that show he made a pretty good fuse; but he did not keep it up. He admittedly afterwards made an inferior fuse, and my point is that he has not yet proved conclusively that the present Economy fuse No. 3 is by any means the equal of Economy fuse No. 1.

At the same time, I do not want to have too much importance placed on these affidavits and this record of experience from customers. I thought we were going

to have 40 affidavits, but Mr. Foote tells us he had 40 letters and affidavits, and he read this morning 14 affidavits. He said he had heard from about 40 inspection departments on the subject. Now, there are something over 240 inspection departments in this country, and he had affidavits from 14 of them.

Let us look at those affidavits. Let us take Mr. Tousley's. Mr. Tousley recites that he is city electrician of Chicago, and that in the territory under his jurisdiction he two years ago permitted the use of Economy fuse No. 1, and has continued it for two years in that territory, keeping careful watch of them, and he is quite willing to continue their use in that territory. That is Mr. Tousley, the city electrician of Chicago.

Now let us see what the record is. The records on file here at the Bureau, being the records of the electrical committee of the National Fire Protection Association and the switch and fuse cut-out committee of that association, both of which have been filed here through action of those organizations, indicate that Mr. Tousley, among others of that committee, voted that as a national question a proper response to the inquiry that is before this board for decision was "Not yet has it been shown that the fuses of the Economy Fuse & Manufacturing Co.," etc.; and that committee said, "Not yet." They may have had in mind the various changes, possibilities of changes, or different models; they may have had varying views, varying tests, and varying records, but certainly they went into it carefully. The National Electrical Code stands as a monument of the work of that committee, and it must be believed that the unanimous decision of that committee came pretty nearly stating the best thought on the subject up to that time.

Now you may ask how Mr. Tousley, as city electrician of Chicago, says one thing and as a member of the national committee having to do with this subject says something rather different. You may have felt that there were some mental gymnastics a fellow would have to go through in order to be in two positions apparently at the same time; but it does not strike me that way. It seems to me that Mr. Tousley is quite right in permitting a field experience with this or any other novel type of device in the territory under his jurisdiction where, as he says in his affidavit, he has such a large corps of inspectors who are so constantly watching these devices and exercising such careful supervision over them, and he was quite willing to have the experiment tried in Chicago to get field experience with this device. But as for subscribing his name as a member of a national committee, saying that this device had been shown to be proper to put into the hands of Tom, Dick, and Harry throughout the country where no inspection or supervisory service exists, Mr. Tousley very properly says, "Not yet" under those conditions, concurring in the expressions of the other members of that committee.

And that is the question before this tribunal. It is not a question for the city of Chicago or the city of Washington; it is a question for the whole United States. And remember, please, that the number of electrical installations that are actually inspected in this country is comparatively small; most of the installations are not inspected at all—those in the country district, those in many of the smaller cities—and while the number of inspection departments has increased, it is not yet possible to get away from the thought that in putting a device out for general use or indorsing it for general use it should be clearly demonstrated that it can not be misused and that it is efficient for the purpose intended.

I conceive that Mr. Boyd, whose affidavit was read, takes exactly the same position. He is a member of this electrical committee and in his position as a member of the national committee he says, "Not yet;" whereas in the territory under his immediate supervision he is content to let the thing be experimented with, and he sees a good deal of virtue in it and is in favor of trying it out. The same is true of our friend from Cleveland. Mr. Patton is a member of the executive committee that indorsed the action of the electrical committee, saying they thought it was a wise and proper decision to say that the experience with this fuse was not sufficient to warrant them in

recognizing it in the code. They did not say that it might not be; they did not say definitely that it is not a good fuse; they said, "It has not yet been shown."

There have been various interpretations placed on what one committee said or another committee said, but the authoritative interpretation was placed on it by the executive committee, and they said that the sum and substance of the whole thing was contained in those two words; that the answer to this question that is before you for decision, in the opinion of that executive committee, and what the electrical committee intended to say, was "Not yet."

I do not see how you can say after this evidence to-day either a positive yes or a positive no, or give a positive assurance one way or the other on this fuse, unless you are willing to take the position that a device that, after all, has had a comparatively limited field experience, that has not been on the market for more than a year, roughly speaking, and that has not been introduced in what we call very large volume as compared with the total volume of fuses—how you can deduce any other conclusion than the one that was arrived at by that committee that has been considering this matter for so many years. It is needless for me to refer to the personnel of that committee or the people they represent.

I want now to refer to the "young library" that Mr. Foote has filed here in the way of letters from customers or answers to the questions that were sent to the users of these devices. I presume that your experience is very much like my own; that across your desks every day come letters from users of various appliances indorsing them for reasons which are to them sufficient. Well, other branches of the Federal Government have brought action and practically put out of business a good many concerns in this country whose whole stock in trade was indorsements from users—drugs which had no proper healing value, and mixtures and food products of all kinds. It is the history of numberless fire appliances that those that have received apparently the greatest volume of indorsements from their users or, at any rate, whose makers have appealed to the users to secure the greatest volume of indorsements, have almost universally failed sooner or later in practical experience. We do not find the makers of standard wares speaking very often or constantly of the opinions of the users.

We had the case of a dry-powder fire extinguisher, so called. It was a tin tube, worth about a nickel, which held a few cents' worth of bicarbonate of soda and iron filings, painted red, and said to be good to extinguish fire. The manufacturing cost was possibly in the neighborhood of 15 cents, and they used to be successful in selling them for $3 apiece, sometimes less but generally about $3. The enormous sales expense, perhaps, justified the price, because they went about the country making all sorts of demonstrations. They used to go into a man's office, set fire to gasoline in a cuspidor, sprinkle this powder over it, and the fire would go out, of course, because the gasoline would act on the bicarbonate of soda and it would stop the combustion in the cuspidor. That appealed to a great many buyers and users. They did not stop to consider that the actual case where you have a gasoline fire in a cuspidor is exceedingly rare. We have very few gasoline fires in cuspidors.

Now they had the most wonderful testimonials from users. They used to come to our office every day with these testimonials in great volume as to the wonderful things they had done—in such great volume that we used to measure them instead of reading them. We would say we had a foot or a foot and a half of testimonials this week. They were perfectly sincere, these men. The user always likes the thing he has got in his plant; he buys it on his own judgment and it is certain that he never will speak to an insurance inspector adverse to anything he has in his plant, be it an electric fuse, a fire extinguisher, or something else.

Now, what happened with regard to this dry-powder fire extinguisher? They went on impressing their views on the public, and among other places they installed one of these tubes in the Iroquois Theater in Chicago. They had a fire there; some of the

curtains and draperies caught fire. This thing was labeled "For fire"; it was right there, and the man who was operating the spotlight seized this tube of powder and began waving the wand at the fire. Of course, it had no effect at all. The only theory on which you could put out a fire in that location would be that you might haul in a carload of bicarbonate of soda.

Six hundred and twenty-four people—men, women, and children—were burned to death in that theater just on the false sense of security given by that appliance; and the very next day after that occurrence took place every one of those dry-powder fire extinguishers on sale in the city of Chicago was sold and they were taken into happy homes in the happy thought, "Now we will have a fire extinguisher in our homes after this terrible happening at the Iroquois Theater." Which shows that the people do not know; you can not expect them to know. You can not expect a user, a fellow that has perhaps to replace a fuse once every year or two, or a man who never has to use a fire extinguisher, to know all about the technical nature of this business and to know whether he has a good fuse or a good fire extinguisher. And I do not attach very much more value to all these testimonials from users in respect to this device than I would in respect to any other device.

To be sure, there are a number of people there who have good engineers and large plants and who are presumably very much interested in this thing, but their point of view is, after all, a selfish point of view. There are several things to be gained by them from the use of this fuse—cheapness, always a factor; convenience, always a factor. They like it for those things alone and commend it for those things alone. I can not blame them; but that sort of testimony, the fact that the fuse is cheap, the fact that the fuse is convenient for some people, especially convenient, is not involved in the question that is before you, in my opinion. The only question is the one of the fire and accident hazard of this appliance, and you will therefore undoubtedly put the proper weight on these volumes of testimonials, as well as remember the limited scope of the affidavits and the territories to which they apply.

I need not go into our record, the record of our tests, of all the opinions of all the various people that have registered data with you; it would be merely taking up your time. You have reviewed it, or will review it. The main point that I wish to impress upon you is the thought that a conclusion of this question that has been reached by men who have given it study for a number of years, who have made tests from year to year, who have had available laboratory data from the Underwriters' Laboratories and the Factory Mutual Laboratories, and the other laboratories, men representing not insurance interests alone but various city governments, various national societies, the American Institute of Electrical Engineers, the National Electric Light Association, the American Street Railway Association, the National Supply & Jobbers' Association, all great organizations that are interested in this matter and this code have registered an answer to this very question that is before you. They have registered it, I think, three times, and it has been supported by the executive committee of the same organization. It has not been a negative; it has not been a positive. They have said, "Not yet." And unless a device with a comparatively limited experience in an important matter like this can be judged hastily, I can not see that the answer you will give to this same question can differ very materially from the answer they have given.

STATEMENT OF GUY CUNNINGHAM, REPRESENTING SEVERAL MANUFACTURERS OF APPROVED FUSES

Mr. CUNNINGHAM. I have been asked to present the views of manufacturers of approved fuses. This proceeding is not one which has been agreed to by them; they are not parties to it; but they are included in the invitation to present the statements of fact here, and are glad to present to the Bureau their opinions on this subject and

such facts as I have been able to gather in the short time which was available. I have had the advantage, as regards facts, of consulting only the D. & W. Fuse Co. and the Chase Shawmut Co., and the facts which I have to present are from them alone. Certain other of the manufacturers of approved fuses are here represented in person and will speak for themselves, but I think that the position which I am taking is one which is shared by all the manufacturers of approved fuses, and that is, briefly, that no fuse which is intended to be refilled by the user ought to be approved by the underwriters. This is a thing in which they are entitled to speak from their experience of a great many years with some positiveness, and with, I think I can fairly say, a good deal of disinterestedness, because they are perfectly ready to make any type of a fuse. They can make refillable fuses, if the underwriters want to pay the losses for the people, but they think that they ought to tell you what they think is a correct type of fuse, and that is what I have come to state.

Before the year 1900 the refillable fuse, or renewable fuse, was *the* fuse. It was the custom of the user to put in a new fuse link whenever his fuse burned out. They had fuse links that would stand anything short of a dynamite explosion, and the user put in what suited his fancy as a fuse link, and then the underwriters paid the loss, and the affairs got into such a condition that the fuse was about as dangerous as any part of the fire risk, and the underwriters asked the manufacturers of fuses to get together and make a fuse which would stand the strain and could be approved.

Before that time certain of the manufacturers had decided that a better type of fuse could be invented and put on the market. Mr. Downes, of the D. & W. Fuse Co., developed the type of fuse in which the arc is choked by a powdered material, and Mr. Downes made this fuse so successfully that, as Mr. Merrill has well said, it is the cardinal point of the inclosed-fuse construction, and has led to the development of fuses, so that now instead of being a point of danger they are negligible as the cause of fire injury.

Of course the original Downes fuse was improved by a great many small details, and some of them of great importance, and all the manufacturers shared in this improvement, so that by, say, 1904 the National Electric Code was enforced, to which is due the credit of this system of fuses which has avoided the fire hazard from fuses in great measure. You will find fuses refilled by the user, of course, but as Mr. Foote has said, you can not prevent a man from misusing his apparatus. A man can put a strap of copper across the base of the cut out and carry the current, even if you make your fuse so that it can not be wrongfully used, but in practice fire risk from the filled fuse has ceased to exist as a serious factor since the National Electric Code standard fuses were put out.

The cardinal point of that National Electric Code was that every fuse on the market should bear the label of some one who was responsible for that fuse; that is, the "D. & W." or "G. E." fuse, or "Johns-Pratt" fuse, and those makers will stand back of it. They may make imperfect fuses sometimes; some of their workmen may be careless, but their fuses are tested and they will be improved and little danger will happen; and if the fuse is to be refilled, then there must be some refilling label from some responsible person. When you come to a fuse refillable by the user, however, there is no one back of the fuse who is responsible.

If you are asking the Underwriters to approve as a fuse manufacturer little Johnny who has read about fuses in the schools, or the head porter, or anyone who is going to make a fuse, as he usually wants to make one that is a little better than the manufacturer made, to show how smart he is, that is a thing which should not bear the stamp of approval and the label of a manufacturer of approved fuses, and if the user is to be allowed to refill that it is of no value whatsoever.

I need not argue that the standard form of fuse is a perfectly safe fuse when first made. That is admitted, and it is, I think, practically admitted that in the sizes

which the manufacturers do refill, which are only the larger sizes, that it is properly refilled and it is all right, and if the user tries to refill it it is undoubtedly dangerous, just as the Economy fuse is dangerous.

Now comes the question of whether we shall break absolutely away from that salutary rule that the Underwriters will not pay the losses caused by those who tinker with fuses, and that fuses are delicate instruments not to be handed over to be made by anyone who comes down the pike. The Economy fuse is based on the idea of making something so cheap that no one will want to make anything cheaper, and that it is safe for that reason. I do not agree that that is the result of the use of the Economy fuse. It has been intimated that the fuse manufacturers have been moving heaven and earth to prevent the Economy fuse from being approved. That is, in my opinion, an absolute error. The underwriters proceeded in this matter purely from a conscientious sense of duty, not to put on the market or have put onto the market a thing which is a danger to the public. So far from the manufacturers of approved fuses having "moved heaven and earth" to discredit the Economy fuse, the two companies which I am representing have done practically nothing in regard to it. Each one has made tests enough to see that, in its opinion, the type of fuse proposed is dangerous, and that information was necessary to their business, but it was not developed by running around and spying on the different places where the Economy fuse was used or trying to find out even what the fire risks were.

It is the Underwriters' case here against the Economy fuse. The fuse manufacturers do not feel that they are under the obligation of hunting up what has been the fire risk from the use of the Economy fuse. When the matter was first called to my attention, after this notice came out, I made some effort to speak to some of the underwriters and see what the fire hazard had been, as a matter of curiosity, or to present it to the committee, if it was not presented otherwise. I found that one of the underwriters had been sued. I understood a whole lot of others had been sued, and counsel advised them to keep their information for the courts. That is not a very good way to get information before the Bureau if they are going to sue everyone who dares to disagree with them.

My clients have not gone into the examination of the field record of the Economy fuse at all. They know the idea is wrong, and they will not go into that idea unless they are commanded to do so by the Underwriters and the Bureau.

I do have, however, one letter which is quite illuminating, I think, on the question of whether an Economy fuse is liable to a misuse by the user. This letter is signed by the Sullivan Machinery Co., and was written to the sales agent of my client. It was obtained just by chance, because he understood that this sales agent was proposing to sell renewable strips for the Economy fuses, whereas I think the sales agent wanted to sell Shawmut fuses. The letter is as follows (reading):

> Referring to the call of your Mr. Masterson regarding fuses for our chain machines, have taken this matter up with our engineering department who state that it will not be necessary to send you blue print but simply the following information from their recent letter to the Economy people.
>
> If this does not give you sufficient information, please advise.
>
> We have finally decided that we would like the links for our special Economy fuses to be about 50 per cent heavier than our present ones and have instructed our purchasing department to order the next lot of fuses and links for 250–V–150 amperes, and 500–V, 80 amperes.
>
> We sincerely hope you will be able to give us the above, as we find that the machine operators do not like this fuse arrangement as we have it at present on account of the frequency of the fuse blow-outs, and they either put in two fuse links at once or beat a piece of copper wire to the correct thickness and use that for a link. Our motor is amply large to stand the 50 per cent overload, and we know by experience that your fuse holders will also stand up under this heavier load, so we anticipate no trouble in making this change.

That is what is going to happen when these fuses are put out.

That letter was merely obtained by chance, but we know that the man in charge of the machines intends to put on enough to make the fuse hold. The Economy fuse is sent out with two links, and when it blows there is not much danger of another blow-out, because a man has two links and by putting in both there is not much danger it will occur again.

The whole design of the Economy fuse is to substitute what is supposed to be American inefficiency and cheapness for something which is really good.

The cardinal feature of inclosed-fuse construction is the powdered filling material which chokes the arc, which results in wonderful efficiency. A fuse properly made will operate wonderfully well with that arc-choking material. When that is omitted, the fuse has no function whatever except to keep the metal from blowing around. It would be much safer, so far as the apparatus is concerned or so far as holding an arc is concerned, to absolutely omit the cartridge from this fuse, provided you had it in a place where the spattering metal would not do any harm. The old fuse boxes such as I have seen in the old patents, and which exist in other places which have lots of room, would be very much safer fuse construction with open links than Economy fuse, for the reason that when you omitted that arc-choking material the fiber case has no function except to keep the metal from spattering around, but holds the metal vapor which may carry the arc and cause the fuse to hold, and that is what the fire risk is mostly.

The omission of the arc-choking material was not a novelty but simply a reversion to a discredited type of fuse. Fuses in cases were old before 1895, but the Underwriters found that those fuse cartridges, with no finely divided material, held the arc and caused all sorts of bad fires. The Economy fuse is, of course, very much more effective, even with the inclosed case, than an ordinary flat link without notches would be. The Siemens and Halske patent of 1901 showed this drop-out construction, and it was no novelty invented by the Economy people; and if you are going to use an open-link fuse this drop-out construction is very effective in preventing the arc from holding in a substantial number of cases, but it is not the same as a fuse link surrounded by a finely divided filling material. If this Economy fuse had the finely divided filling material, it could be made when it came out perfectly good. There is no difficulty in making a refillable fuse and making it perfectly good, when it starts from the maker's hands, and I have not any doubt the Economy people could make a perfectly good fuse if they wanted to, at the start, but they want to have something that the user can refill, and so they leave out entirely the powdered filling material. If the fuse was sent out with the powdered filling material, it could not be renewed without new filling material, which would be a considerable nuisance. It would very likely go badly if you used the same filling material, because there would be molten metal all through it; and then, owing to other reasons also, they feel it desirable to leave out the powdered filling material. That is one thing that makes the Economy fuse go badly on short-circuit tests.

One would think to hear Mr. Foote that the Underwriters had approved his fuses. I heard him read statement after statement, and I wondered what the need of the Bureau of Standards was here, because it seemed from all he read that the Underwriters thought his fuse was the best ever. I have before me the report of November 29, 1914. Mr. Merrill will know more about it than I do, but it says "October 19, features criticized include failure on short-circuit test," and that is what I understand the difficulty is with the Economy fuse, but it certainly bears out the tests which have been made by the D. & W. Fuse Co., one of my clients, and by the Chase Shawmut Co., another one. We have tried the Economy fuses and they do not operate satisfactorily, or did not operate satisfactorily on short-circuit tests, particularly when renewed. I am not going to read those tests at length, because they are in the statement which I will file, and Mr. Foote will have an opportunity to look at it.

Also we found that the fuses grew progressively worse; at every time they were tried they were a little bit worse than the time before. Some of them get soldered after a short time so that it was not possible to renew them without putting them in a powerful machine to get the case off, which we did not try to do.

There is another difficulty with the Economy fuse, and that is that it is not a soldered fuse. That is also in the line of making something cheap instead of something good. If you want to get a good contact, you want to have your fuse soldered. But, of course, the user will not have his soldering materials at hand, and so they provide a contact which, when it leaves the Economy factory is perfectly good, a screw contact, but after being used a few times it begins to oxidize, and the user is not skilled in making contacts and that contact will grow worse and worse, and that is the thing for which an extended experience is absolutely necessary. Three months or a year or even two years will not produce all the trouble from this bad type of fuse.

When the contact is bad the fuse will probably blow on the copper, which is one of the very great dangers. If you get a fuse so that it blows on the copper and it happens to be bad at both ends, you will certainly have something which will hold the arc and will certainly not stop until something else breaks the circuit, and also that will heat the case even if you don't get an arc which holds. The bad contact between the copper part at the terminal and the fusible link will make the fuse very hot and tend to char the fuse case.

Take another feature. Is it true that the Economy fuse, being very cheap, is going to be one which will always be properly used, whereas the approved is very expensive, and therefore there is a great tendency to use a bad thing? I maintain, in the long run, the Economy fuse, from the very fact of its greater expense, is going to be a very much greater fire hazard. The Economy fuse costs three or four or five times as much as a standard fuse. The fuses of 60 amperes and under, of the standard make, cost 9 cents apiece. The cost was a little less, but the price has been increased to 9 cents. The Economy cost is 25 cents. A man can use practically three of these low-capacity fuses absolutely new before he has the expense of the Economy fuse.

When it comes to the larger sizes, it varies from four to five renewals, which are necessary before you get up to the expense of Economy fuses. I contend that 9 cents is not too much to pay for having an article which has come from the laboratory, and not one tested by some person who may not be competent.

Is not the temptation rather that a man who has once got an Economy fuse, which he is told can be refilled 75 times, is going to get his money's worth? He is not going to throw away that 25 cents; not at all. It is not like a cheap 9-cent fuse. He is going to refill that until it has caused the fire hazard, has burned out, or has exploded, and that is the cardinal reason, to my mind, why the Underwriters should not be asked to approve a fuse refillable by the owner. He has no spare casing, and he is going to keep on filling that Economy fuse until it has blown out, whereas in the standard fuse he can not refill the smaller sizes in any effective way, and it is not very easy to refill the big sizes.

These people, most of then, are more or less innocent, just as the man from the Sullivan Machinery Co. was. He did not have any idea he was doing a grossly improper thing when he stuck in two links. He thought the case would stand it, and also stuck in a piece of copper wire. He did not realize copper was the greatest arc-holding material and carries the greatest heat, and so on.

When the approved fuses are refilled improperly, it is usually some such performance as this. It is perfectly obvious to the inspector that those are refilled. It can be examined and proved, but it is not easy to prove that when you examine the Economy fuse and try to pull the end off after blowing once or twice. They stick pretty hard, and if you want to refill you have a pretty long job on the inspector's hands. Practically all of these cases I have seen here of fuses improperly refilled can be readily detected by the inspector.

And, after all, is this Bureau of Standards going to say that the public is so dishonest that the Underwriters have got to be asked to approve fuses that are improper, because otherwise the public will frequently use fuses wrongfully? I do not think that the Underwriters or the Bureau ought to take any such position.

STATEMENT BY H. R. SARGENT, GENERAL ELECTRIC CO., SCHENECTADY, N. Y.

Mr. SARGENT. I have had the pleasure of acting on the American Institute of Electrical Engineers Code committee, which committee considered the safety-first rules, which have been promulgated by your Department. I believe, and for that reason I am rather in touch with the work you have done, and I feel, I think I am entitled to feel, that you are naturally anxious to obtain the safest possible devices, even at slightly increased cost to the consumer. The standard fuse manufacturers must, of course, admit that their fuses are occasionally reloaded improperly, and naturally the reloadable people must admit that their fuses are capable of being reloaded improperly. If such is the case, it comes down to a question of invitation on the part of the Underwriters' Laboratories to the general public to reload fuses. At the present time the small sweatshop operator, and even small manufacturer, who presumably could reload fuses properly, if he was so minded, has been taught at considerable expense that the fuse is of vital importance to the protection of apparatus, and if they are taught that they must not fool with these fuses and try to reload them, it is fair to assume that fewer fuses will be improperly reloaded with the present stand which has been taken by the laboratories—namely, that the reloadable fuse shall not be used—than will be the case if the general public is invited to reload fuses. Just as soon as the general public is invited to reload fuses, in my opinion, the day of the inclosed fuse, reloadable or otherwise, has gone by, because these fuses will be reloaded by Tom, Dick, and Harry, and it can not be denied that fires will result, and not only fires, but eyes will be lost and anything else that may occur from fuses exploding, aside from the lack of protection of the apparatus, so that we must go back to the link fuse for safety. I have been told by underwriters that some of them feel that it would be a poor stroke of business to go back to the link fuse; that the inclosed fuse is a very considerable measure of protection, and while, as I have stated before, we can put out reloadable fuses, we have, however, purely from a safety point of view and not from a commercial point of view, thought it important not to put them out. It was stated here that the ease with which solid copper wires may be used in ordinary fuses is supposed to invite improper reloading, but, as I say, anybody who will do that will certainly do the same thing with a reloadable fuse.

As stated by the attorney here, in every case I have seen the standard fuse reloaded is comparatively easy to detect, although I must state that in some cases drills have been run through ordinary ferrule type of fuses and copper wires have been put in-but in ninety-nine cases out of a hundred fuses which have been improperly reloaded have been easy of detection, and in the exhibits I have seen around in the different Underwriters' offices and inspection departments I should judge you had practically all of the fuses here which have been improperly reloaded. You have quite an exhibit here.

If I may be permitted to say it, great stress was laid on the question of the price, and just for my own amusement this morning I drew a comparison of costs of reloadable versus the standard fuses, and if I might be permitted to put it on the blackboard it would show up better. It may be open to criticism.

(At this point Mr. Sargent placed upon the blackboard certain calculations, commenting thereon as follows):

The list price of reloadable fuse 200-ampere at 250 volts is $4. According to their document here, they give a discount of 50 per cent, which would be $2. We assume 100 fuses would be $200. The list price of reloads is 15 cents each, which, of course,

does not include the labor which the man who buys the fuse must put on the fuse. Fifty per cent off would be 7½ cents. From the best data I have been able to obtain I found there are required 10 per cent reloads per year, while from some of the Underwriters I learn they found 20 per cent; but assume it is 20 per cent—I want to be as liberal as possible—it would be $1.50. That would be $201.50 for the first year. Naturally you add $1.50, assuming you use the fiber cases and always use the ends, except this little fuse element; that would be $203 the second year and $206 at the end of the fourth year.

Take a standard fuse here and I will put it on the 50 per cent basis, although fuses are sold on 64 per cent basis to the trade, which corresponds, as I believe, with the 50 per cent discount. The list price of the standard fuse is $2, of the same size. Therefore, with 64 per cent off, the price would be 72 cents each, or, in other words, on the same basis, $72 a hundred. But, to reload that fuse at the factory is 90 cents, which includes all labor. Sixty-four per cent off of that, at 20 per cent, would be $6.48, or 20 per cent reloads to the year, $78.48 the first year; $6.48 for the second year would be $84.96; $6.48 for the third year would be $91.44; $6.48 for the fourth year would be $97.92. In other words, at the end of the fourth year, with 20 per cent reloads, you have $97.92 against $206. I think I have got that right.

You can see that goes on quite a ways before you arrive at the point where they equalize. The question is where the expense comes in. I do not know whether that is a correct illustration or not. They were talking so much about the cost that I put those figures down.

One other point was made this morning—that they tested the fuses at the laboratories with the filler, and that they were afterwards, as I understood the statement, tested without the filler, and that they operated as well without the filler, and so reported. I do not know; there may be a report to that effect here, but the report was not read; but even so, when the report is read I want to state that I have been in this fuse business for 15 or 20 years, and I know that fuses without a filler will not operate satisfactorily on a short circuit. I have not even taken enough interest to test Economy fuses without a filler to demonstrate. I have patents on fuses without a filler, and I know they will not operate satisfactorily, and I have made numerous tests. As a matter of fact, the other day we had a test of Economy fuses in our power plant, a report of which I obtained recently, but I prefer not to even quote it, because there are so many changes in the fuse. They all blew out. I did not do it for data to present here, but we test our own fuses there at the plant, and we had these two samples. The fuses without the filler, if on short circuit, will not stand up. I do not know what data may be presented here to show that in some tests they have stood up. I do not know what the resistance is, but if placed beside large sources of power, without filler, the fuses will blow out, according to my experience.

Dr. ROSA. Will you send to the Bureau a precise statement of your laboratory test, giving all the conditions of the test?

Mr. SARGENT. I will read this test, if you would like to have me. As I say, I have not presented any data to you of this nature, and have not cooperated with any of the other manufacturers, because our experience in the past is such as simply to make that unnecessary.

Dr. ROSA. We have made a great many tests of that kind, and have seen tests made elsewhere, and we have made a very careful record of the conditions as to resistance and reactance and the power capacity of the source, and we would like very much to have a report of that kind, because we shall desire to repeat them under the same conditions.

Mr. SARGENT (reading):

> Tests were made on the above fuses on Wednesday, June 2, 1915, at 5.30 p. m., outside of building No. 11. Power back of tests was 5000 kw., derived from building No. 13. The voltage was 570 at the beginning of tests and at close was

572. The tests were in accordance with the Underwriters' Code, that is, the leads provided resistance of 0.069 ohm, which was as near the 1 per cent drop with 100 amperes as we could get. The Underwriters had 0.0624 ohm resistance in their New York test September 25, 1914.

1. Economy 100-ampere, 600-volt fuse (drop-out link without filler). Fuse blown out of cut-out about 9 feet. Cut-out blown in three pieces. One end of fuse blown off, leaving just threaded part of cap on fiber. The other end almost blown off, just hanging. A very loud explosion.

2. Economy 100-ampere, 600-volt fuse (drop-out link without filler). Much louder explosion than No. 1. Blew fuse out of cut-out about 12 feet and blew cut-out in four pieces. Blew one end of fuse about 15 feet and the other end was bent outward.

Witnesses: F. A. Barron, F. H. Weston, E. A. Johnson, testing department.

Yours, very truly,

(Signed) H. H. GREENE.

Dr. ROSA. This was a 600-volt circuit?

Mr. SARGENT. 600-volt fuses.

Dr. ROSA. As I understand, the question we are discussing does not include 600-volt fuses.

Mr. FOOTE. That question is not involved here.

Mr. SARGENT. The type of fuse which I mentioned a while ago, on which I have a patent and of which we put out considerable, was 30 ampere, and I guess the other manufacturers made as small, had zigzag barrier across the fuse link, in an endeavor to dissipate the gases, but, of course, the action of the fuse filler in chilling the gas immediately is what makes the fuse operate satisfactorily; where the gas has no chance to chill rapidly the gas is not dissipated rapidly.

Mr. CUNNINGHAM. I should like to make one suggestion. There was nothing in the letter of the Bureau of Standards which gave the slightest indication to the people invited to be present that this was a test of only 250-volt fuses. The Economy company is putting out 600-volt fuses, and having them on the market, as I understand it; in fact, I know it.

Mr. FOOTE. How many of those are used to-day in comparison with 250-volt fuses?

Mr. CUNNINGHAM. I only explained that as bearing on my argument.

Dr. ROSA. I understand that the 600-volt fuses have not been reported upon by the laboratories, and the question we are discussing is limited to those that have been so reported. If it appears necessary that the 600-volt fuses be investigated, I do not know any reason why that might not be done, but it would not be on the same basis as those upon which the Underwriters' Laboratories have made the report.

Mr. CUNNINGHAM. I only wish to give that explanation, because my statement was prepared with no notice or knowledge that there was any limitation on this subject.

I would like to make one more suggestion as to a defect of the Economy fuse. The more it is used the more dangerous it is, on account of the vapor and the molten metal sticking on the fuse case, and that that will heat or cause very serious trouble; and when they are talking about reloading 75 times you would have several feet of metal around there somewhere.

One other thing, and that is standardization of links. There are several refillable fuses on the market, and I have not directed my remarks particularly against the Economy, because I think it is a general subject, and I wish it understood that my remarks are addressed against all refillable fuses and not particularly against any one fuse.

I have in my hand the advertisement of another refillable fuse. There are I do not know how many reloadable fuses, but we assume that each refillable fuse has its own form of link. If we put out one, as we certainly shall if this becomes the proper thing to do, we shall have a form of link, and there will be 18 or 20 forms of link. Is it not fair to assume that the fuse of one manufacturer should operate satisfactorily with the refill of another manufacturer? In other words, the jobber may be out of A's refills,

but may have plenty of B's and C's. The purchaser says, "All right; if you have not A's, I will take C's," and he takes C's and puts them in. One fuse is absolutely dependent on the type of link. He gets some of C's in and they do not operate satisfactorily. We have no assurance that the fuse will operate satisfactorily with "Noark" refills, or refills of one of those other exhibits, and it seems to me they could do that even without the thought they were violating any of the prescribed rules. It occurs to me a very important factor is that a great deal of time has been spent by the standard manufacturers for a number of years with the underwriters in standardizing the dimensions and the size and all that sort of thing with regard to present fuses, and that is all knocked into a cocked hat with all the different manufacturers making different fuses, dependent on different forms of links.

STATEMENT OF PROF. H. E. CLIFFORD, ELECTRICAL EXPERT

Prof. CLIFFORD. It is not my purpose to discuss the general question of fuses, but rather to simply give an expression of opinion in regard to definite evidence, which I have been invited by the Economy Fuse & Manufacturing Co. to examine, exactly as any other mass of scientific evidence would be examined, and then to express an opinion as to what that evidence contains.

The data which I have examined are those referring to the tests that were conducted at Market Street substation of the Commonwealth Edison Co., at Chicago, under the direction of Mr. Conrad, who is, I understand, largely responsible for the testing work of that company. My contact with Mr. Conrad convinces me that he is a man of real scientific attainment as well as of broad engineering experience. He approached the problem which was presented to him by the Economy Fuse & Manufacturing Co. with an absolutely impartial mind, and in discussing the test with him I was convinced that his attitude was an absolutely unprejudiced and most judicial one.

The investigation, as you know, was most extended, consisting of the blowing of over 3000 fuses and the obtaining of approximately 300 oscillographic records. I have examined the records of those tests, the data of which you have, and in expressing an opinion I shall confine myself merely to the results on the standard fuse as it exists in the tests, not referring to a number of records which involve experimental development work. The fuses tested were 30, 60, and 100 amperes in rating, and were both of the ferrule and of the knife-blade types. The records, which I will not discuss in detail, seem to me to show this, that the Economy fuses, more particularly in the ferrule type, show distinct superiority to certain of the so-called approved makes; that taking the results with all of the so-called approved fuses which were tested and the records of which you have and comparing these with the results obtained under precisely similar circumstances on the fuses of the Economy Fuse & Manufacturing Co., there is no doubt in my mind, in analyzing these as a mass of scientific data, that there is no inferiority whatsoever shown in the general performance of the Economy fuse.

I think it is well to note that the circuit on which these fuses were tested came directly from the bus bar with a 10 000 ampere-hour battery always floating on the system, 1000 kilowatts of rotary capacity, and occasionally during the test as high, I understand, as 4000 kilowatts in rotary capacity on the bus bars, in addition to the 10 000 ampere-hour battery. So that there certainly can be no suggestion of lack of generator capacity back of the fuse.

I would also note, which of course would immediately suggest itself to you as of importance, that the constants of the circuit from the bus bars were very definitely known. It is to be remarked, likewise, that the drop of potential at the busses as the fuses were blown was tested from time to time, and the percentage drop was materially less than that which ordinarily occurs on many of the fuse tests that I have had occasion to witness since 1900.

In other words, as the data show, the drop of potential seldom, if ever, exceeded 30 per cent, and I have known of many cases in fuse tests where the potential drop on

busses at the time the fuse was blown was as great as 75 per cent. That shows, therefore, that the conditions under which these fuse tests were carried on subjected the fuse itself to very severe electrical stress.

Considering, then, that the direction of the test was in the hands of an impartial and experienced engineer; that the men who carried out the manipulative work were skilled and experienced in this particular line of work; that the records speak for themselves and have been submitted to you exactly as recorded, I have no hesitancy in repeating the opinion which I expressed a moment ago, that a careful examination of those records will show that the Economy fuse is in no sense inferior in performance to types of approved fuses which were tested under identical conditions.

I can not let pass the remark which was made by Mr. Cunningham, that the Siemens and Halske patent, with which I am familiar, is in any sense an anticipation of the Economy fuse as at present manufactured. The idea that the drop-out link when used in an open-link fuse in any sense anticipates the use of the drop-out principle in the cartridge type is just as sound, and no more so, than the idea that the open-link fuse anticipates the same type of link when placed in a cartridge. The things are entirely different; their performance is entirely different; the oscillograph records, of which I think you have some, show that they are entirely distinct; and therefore to refer to this old Siemens and Halske patent as a discarded method of attacking the problem which has been revived by the Economy Fuse & Manufacturing Co. shows, in my judgment, a lack of just appreciation of the fuse situation.

I am now informed by Mr. Huxley that you have not those oscillograms to which I have just referred. I think he would be very glad to show them to you. I have witnessed the test of the drop-out link and the single-notch link in the open-link fuse in comparison with the same link used in the cartridge fuse, and the difference is most marked.

It seems to me that no fuse construction and no electrical construction are necessarily final; and if the Economy Fuse & Manufacturing Co. have made a real advance and have the courage of their convictions, I think the evidence they submit—not the evidence of opinion, but the evidence of actual test—should be the determining factor.

STATEMENT OF LOUIS W. DOWNES, GENERAL MANAGER D. & W. FUSE CO., PROVIDENCE, R. I.

Mr. DOWNES. I regret the confusion that has arisen on this question of whether the subject covered the entire field of inclosed fuses or not, because we certainly were under the impression that it involved the 600-volt fuses as well as the 250-volt; and I am still further confused by the statement that no report has been made by the Laboratories on the 600-volt Economy fuse, because I have in my hand two photographic copies of the report issued by them on those points. Mr. Cunningham referred to one of them. The fact that the Economy people, in the face of the report, which criticized their operation on 600 volts, continued to market and advertise them as broadly as they do as the par excellence of fuse design, would seem at least to be a questionable attitude on their part, in view of the argument presented to-day.

One of the greatest difficulties which the manufacturer of inclosed fuses has experienced—and I speak from a very long experience in this particular line of work—has been the continued demand by the user for an increase in capacity of a given size of cartridge fuse. He might have installed a 60-ampere fuse, the limit of that particular size under the present rating. He would come back to the factory with an insistent demand that he must have a 65 or a 70 ampere fuse to go in the same cartridge, or it might be even worse than that. He might have a 200-ampere fuse and insist that he must have a 300-ampere link to put into the 200-ampere case. That is something we have all had to contend against, and the Underwriters will bear me out that it has been the subject of discussion between us on numerous occasions, and it shows the

general tendency of the public to ignore, first, the danger, of which they are wholly ignorant, of overfusing a given size of case, and disinclination to take out the cut-out which is already installed, if they find the fuse is of too low capacity, and install the next largest size. That sort of thing necessarily is a factor which has to be taken into serious consideration on the question of this refillable fuse, because of the facility which presents itself for an increased capacity by multiplying the number of links; that is, by the use of two or three links, which can be readily done in a given cartridge, and that is something that will inevitably result from the use of that type of fuse.

Speaking of that, as I do, from a great many years' experience, and knowing this pronounced tendency, it is something I believe this Bureau should take under careful consideration.

Another point that I wish to emphasize which has not been touched upon directly. Mr. Merrill in his talk spoke of the appointment of additional members to the existing switch and cut-out committee of the National Fire Protection Association, for the specific purpose of investigating the use of these fuses. They made a careful study of the problem for two years, and unanimously reported against any change in the Code, which permitted the use of that type of fuse The chairman of that committee, a man of the widest experience in insurance, was directly connected with the inspection department of the Factory Mutuals, and that department had the best opportunity in the world of observing these fuses in field service, and for some time the Factory Mutuals, insuring property of over two and one-half billions of dollars, have refused to permit the general use of those fuses in the large plants that they cover. They must have had some reasonable grounds for that attitude. It is undoubtedly true that in certain cases where they knew that the work of refilling would be done by a skilled man and one who could be relied upon to do the work properly, they would permit its use, if requests were made; but I am speaking of the cases which have come under my own observation, where they knew that the Economy and other types possibly of refillable fuses were installed and they have actually ordered them out of the plants.

It seems to me right there is a subject for a good deal of thought, because they are not the kind of people to take a radical step of that kind unless they believed it was a hazard to the property which they insured.

Mr. Foote in his argument gave some figures as to the total number of fuses which they have sold in the last two or three years, amounting to about a million, and it has occurred to me to suggest that investigation of the total number of fuses in use in this country at the present time, as a manufacturer knowing approximately the productive capacity of my competitors has yielded some figures which may be of interest. I find, on a conservative basis, that there are about 6 000 000 fuses produced each year; in other words, in 10 years we would have 60 000 000 fuses turned out. Taking a little higher average of renewals than that used by Mr. Sargent, 20 per cent, let us say 30 per cent, which would mean that at the present time there are approximately 40 000 000 fuses installed. If we admit that 4000 fuses a year are improperly renewed in the manner indicated in those exhibits, we would have 0.4 of 1 per cent of improper refilling of the fuses installed. Now, as a matter of experience, I know that the total number of improper renewals coming back to our factory—and we get them sooner or later, as they are returned for renewing in the sizes in which we do that work—is insignificantly small. I could say that 25 to 30 fuses a year would be a maximum that we have ever received in our history of fuses returned to us which had any indication of improper renewal. So that by conceding 4000 as a maximum I am giving a very wide margin of safety.

This problem is one that we have considered for a great many years. We have one of the earliest patents on the renewable type of fuse, but for the reasons that have been well expressed here to-day we have never put that type of fuse on the market, although we knew that a possible demand existed.

At a time slightly before the standardization of the inclosed fuse this whole matter was under very lengthy discussion by the insurance interests of the country, represented in the biennial meeting held in New York, and that particular feature of making a fuse as difficult to renew by the user as possible was one which underwent lengthy argument and discussion, and it was practically the unanimous opinion of the insurance interests represented at that meeting that there was necessity for the wording that is in the Code to-day. They had serious grounds for taking that position. Accepting that principle, and converted to it as it were at the time by the arguments presented, we have always abided by it, and at the same time we want to make it clear that the construction of a refillable type of fuse is not and can not be confined in any way. At the present time we have a type of refillable fuse completed and designed and tested, which can be put on the market, if that situation is forced on us; but we would do so against our better judgment, for the reason that our long experience has shown us that too great care in the construction of the inclosed fuse can not be taken.

To indicate something of the care which is taken in my own factory, I would say that there are continuous tests going on in that plant 300 days in the year to check our product, to see that it comes up to the standard. At intervals we take fuses and subject them to the short-circuit tests under the conditions outlined by the Underwriters as to ampere capacity, and the tests which Mr. Cunningham submits in his report were an indication of the class of work that we are doing in order to keep our product up to the highest possible grade to fulfill the conditions which the Underwriters have imposed in their wisdom. And now to eliminate that care, that study to which we have given our entire time for 15 or 20 years and going right back and putting the construction of the renewal of the fuse into the hands of the ignorant public, who know nothing about what takes place in the fuse, seems to me a very unwise step. Examine, yourself, some of those fuses that are exhibited, as an indication of what we are liable to run into. There are fuses which are being sold to-day, put on the market and advertised as high-grade articles, high-class material, that I know from my positive knowledge of fuse design as applied to those particular types, can not operate satisfactorily under short circuit, and constitute a desperate fire hazard and life hazard in themselves.

I have with me a fuse which has recently come out [illustrating] under the name of "Hickman," of Harrison, N. J., which gives an indication of the class of people who are getting into the development of inclosed fuses. Here is a glass tube onto the ends of which copper has been apparently electroplated or sprayed, a fuse wire of considerable size being passed through the center, now being made in the dimension of the 30-ampere, 250-volt class. That man evidently is perfectly honest, because he sent that fuse to us for our examination and test, with the idea of disposing of his patent if he could. That sort of thing has been on the increase within the past two years, during this period of field trial, and all sorts and conditions of people are getting into the construction of inclosed fuses and the designing of inclosed fuses.

As a matter of interest I had two of those short circuited under only moderately severe conditions yesterday morning before I took the train, and the result to a man examining a panel board equipped with that is something you do not want to think of. If the short circuit occurred when a man was examining that panel board, he would lose his eyesight with a chance of a thousand to one.

During the past two years of this period of field trial upward of 22 to 24 manufacturers have started into the inclosed-fuse business. Several of them are represented in the exhibits shown there to-day. A great many of them are marketing their goods extensively to-day which have never been submitted to the Underwriters for consideration or approval, so far as we are able to learn; or certainly, they have never passed any test of the owners, and that is just an indication of what will take place if this field is opened and everybody could make his own fuse. We are going to have hundreds instead of as at present 28 or 30 manufacturers of inclosed fuses, because it

requires a comparatively small plant to assemble some caps on a fiber tube, without any experimental equipment or testing equipment, and we know positively of one case where a man has been manufacturing inclosed fuses in his cellar and back room for the last two or three years, and marketing them quite extensively. He has two or three operatives there; no facilities or equipment. He just takes a piece of lead wire of any convenient size which he may have on hand and drills a hole through the cap and solders it in, and that fuse goes out. If his customer wants a 50-ampere fuse, he marks it "50 ampere;" if he wants 75 amperes, he marks it "75 amperes." We have tested a number of them, so that I can speak positively as to the varying capacity of the same sizes of wire used in the different tubes.

Dr. ROSA. I would like to ask Mr. Downes if he understands that the proposal under consideration is to relax all requirements on fuses if refillable fuses were to be approved? Did you understand that any kind of fuse could be used at liberty, in case refillable fuses could be utilized?

Mr. DOWNES. I do not.

Dr. ROSA. I do not quite understand the last statement made.

Mr. DOWNES. Possibly I can make myself a little clearer in this way. At the present time the manufacturers of fuses have definite arrangements with the Laboratories by which frequent tests are made of their product. The representatives of the laboratory come into the factory, take goods at random and test them out, and at intervals short-circuit tests are arranged for—at less frequent intervals on account of less opportunity—so that every possible effort is being made, not only by the Underwriters' Bureau, but the Laboratories, to keep the standard up to a high level. It is perfectly obvious that the manufacturer, if he is making refillable type of fuse, can have no further interest in the Underwriters' Laboratories inspection, for the very simple reason that the only thing they can do is to make measurements of the visible dimensions of that fuse and see whether it conforms with the Code dimensions, or to test out the fuse as it goes from the factory. After it gets into the hands of the consumer and is refilled, the manufacturer certainly will not take the responsibility of the operation of the device, so that the influence of the laboratory toward maintaining a high standard of manufacture is necessarily bound to end right there. They can only say that a fuse as it comes from the factory is a good fuse, or, if it happens to be defective, they will call the manufacturer's attention to it. After it gets into the hands of the consumer, they can not tell, unless they take that fuse out and take it back to the laboratory and make a test of it, and I know from my general knowledge of the subject of inspection that they could never hope to do that. I think Mr. Merrill will bear me out in saying that that would be an utter impossibility. They can pick out one here and one there, and send it back and see, but the interest of the manufacturer ends—and I believe that I can speak for a group of manufacturers, although I am not authorized so to do—and any laboratory inspection of the renewable type of fuse will cease to exist as soon as the Code is changed permitting those to come out, because the test does not amount to anything.

So far as the test arrangements exist, we are doing and will continue to do everything in our power to keep the standard up to the highest possible level. That has been our aim for years. We are under constant and very heavy expense. Take my own concern alone, which is not a large concern. Our laboratory is spending $10,000 a year in maintaining our quality. There are other manufacturers that I know spend an equal amount. We can not continue to do that as long as the construction of that device may be wholly and entirely changed, due to the ignorance, carelessness, or indifference of the man who is using it, and, as I pointed out, the general tendency is, if your fuse blows, to put in a bigger one. Protection they do not consider, but simply put in a bigger one. I can give you an instance which will illustrate that rather clearly, of a building in New England which was using a refillable type of fuse.

Mr. FOOTE. May we have the name of the place and the name of the man?

Mr. DOWNES. I can not give you the name of the man, but it occurred anyway.

Mr. FOOTE. Then we can not check it up?

Mr. DOWNES. I can have it checked up, yes. His renewable type of fuse blew, and he was criticized by the management. It was a factory building. He said the lights were going out. "Can you stop that?" He said, "I will fix it." So the next time he put in either two or three links, so that the capacity of the fuse was immensely increased, and when the overload came on he blew his primary fuses, and then with a great deal of glee he said, "It is not up to me; it is with the lighting company. When trouble comes it is not up to me. My fuse did not blow. Theirs was the fuse that blew." That tendency you can not eradicate from the using public, and I speak from a great many years' experience in contact with those people freely, and I know they will proceed if a fuse blows to increase its capacity, no matter what happens.

Dr. ROSA. Is that also true of the nonfillable fuse?

Mr. DOWNES. It is the difficulty which they experience in increasing the capacity, that is the safeguard. As I have already stated, they finally write and want a 65-ampere fuse in the 60-ampere cartridge; but we positively refuse to do that.

Dr. ROSA. Is the general tendency of the users of fuses to put in a bigger fuse when the 50-ampere cartridge fuse blows, for example, so that the next time it will not blow? The users do not carefully regard protection, and the tendency is to use a bigger and bigger fuse until it ceases to blow. Is that your understanding?

Mr. DOWNES. There is this tendency, to slightly increase, not to go to the next size. As I say, it was difficult to induce them to take out the 60-ampere block and get them to put in a 100-ampere block, so they could very properly use 60, 75, and on to a 100-ampere fuse. They will not do that. They will ask a manufacturer to give them 65-ampere fuse links in a 60-ampere cartridge, or if it happens to be a 100-ampere cartridge they will ask him to give them 110, 115, 120 ampere links for that 100-ampere cartridge. In other words, that is the tendency. When a fuse blows, they do not reason "Now, let us go and look up the trouble and see why that fuse blows. Was it a defect in that motor? Was there a short circuit on the lighting line, or was the load up to the limit, or something of that kind?" But they promptly put in a bigger fuse.

That has been the tendency, and it has been my experience for 25 years. I was formerly, before I started the D. & W. Fuse Co., in the employ of the Narragansett Lighting Co., of Providence, and had a splendid opportunity of examining that trait, because we were continually getting complaints, where customers had refilled their own open blocks when they were in use. And I would find 60 and 70 ampere open fuses installed on a cut-out whose normal capacity would not exceed 100r 15 amperes, because they would have trouble in the line and the only idea was to keep increasing the capacity of the fuse until it stopped blowing.

Mr. CUNNINGHAM. I have been asked by the Chase-Shawmut Co. to state—and I think the Johns-Pratt Co. also said—that if their fuse was to be regarded as a standard after it was filled by the janitor or porter or anybody of that kind they would regard the approval of the Underwriters as a trivial absurdity and not feel justified in going to any trouble to have it done.

Mr. FOOTE. If refilled by the factory, are they approved by the Laboratory or submitted there for tests?

Mr. CUNNINGHAM. I do not know whether they are tested.

Mr. DOWNES. They are tested and approved. I think Mr. Merrill will bear me out that the arrangement with the Underwriters is that when we refill a fuse that is returned to us for that purpose we put our label on it, and we stand back of it, and that is made in accordance with the standard construction employed by us and used on the types of fuses which they test from time to time. They are at liberty to test those whenever they see fit.

Mr. FOOTE. You do not submit to tests each new job?

Mr. DOWNES. They do not ask us to.

Dr. ROSA. I would like to ask a question about the renewing of fuses. It is the practice in some places for local concerns to renew the so-called nonrefillable fuses. Is there any connection between the manufacturers of renewable fuses and these local concerns; any guaranty that the refilling by the loc al concerns is done properly

Mr. DOWNES. None whatsoever. We have taken every step we can to eliminate that sort of thing, because we find the work done by these people, who may be said to be specializing on refilling fuses, is very indifferent in character—the capacity of the fuse, its rating may be anything at all—and we have no connection with them, and in several instances we have brought suit against them for infringement of various detail apparatus and stopped them from doing that kind of work. But that is no indication of the carelessness with which the public is liable or likely to do refilling, if it can be judged at all by the work done by these people who are making a specialty of doing it. We have never yet found a fuse that was anywhere near its proper rating when refilled by one of these specialists, so called, the general tendency being to make them very much heavier; in other words, to increase the volume of metal in the link, and on that point we run into the very serious hazard, because, as you have probably determined, a variation of less than 1 per cent in the link means the difference between the fuse operating properly and an explosive fuse when it comes to short-circuit conditions, and we find that they will go so far as to increase the metal volume by from 50, 75, to 100 per cent.

Dr. ROSA. We were very much interested to know what the facts were, and we have some information on that subject which seems as though the protection for making the fuse is lost to some extent, if local concerns are going to make it a business to renew them instead of sending them to the manufacturer. Mr. Downes states it is rather usual when they are so reloaded that the capacity is increased. As a matter of fact we have a specimen taken in actual use which had been reloaded in that way by a local concern, in which the cartridge was filled up—three heavy conductors of fusible wire, practically filling the cartridge—and while that is only one case and may not be typical, it confirms his statement that the tendency is to renew them improperly. I think that is rather an important phase of the question that ought to be kept in mind and upon which we need to have further information. If we could be assured the nonrefillable fuses would only be refilled by manufacturers, obviously that would be a very important fact and a very important protection.

Does anyone else wish to address the conference? Mr. Skinner, representing the Westinghouse Electric Co., is here. I will ask if he cares to make a statement.

Mr. SKINNER. I do not believe I have anything to say at this time.

Mr. FOOTE. I understood all the matters would be laid before this meeting, so that we might have an opportunity to examine them. We are here against a lot of interests to prove our case by facts. Whatever they have to submit should be submitted here, so that we may answer, and that is our understanding of the agreement.

Dr. ROSA. I think Mr. Skinner should have the privilege of preparing a statement of whatever he may have to say and give Mr. Foote a copy of it.

Mr. SKINNER. I would be pleased to do so.

Dr. ROSA. May we hear from Mr. Bates, of the Bryant Co.?

Mr. BATES. I do not believe I care to say anything.

Dr. ROSA. Is there any other person who wishes to make any statement or suggestion before we close? Mr. Merrill and Mr. Foote will close, and either one may speak first.

Mr. MERRILL. I have nothing to add, Mr. Director, except to express the thanks of my people for the very great patience you have shown in this hearing, and the admirable way in which it has been conducted, and the painstaking research on the facts presented. We wish to offer the thanks of the Underwriters' Laboratories and that of our associates for our reception, and particularly for the hospitality shown us.

Mr. FOOTE. I shall not have very much to say, because, as I view it, what has been said requires very little answer, in view of the question submitted here, being one of proved fact and not voluntary statement. There have been two examples of fact suggested, one of which was given some importance, identifiable by the case of the Sullivan Machinery Co., and I will ask Mr. Eustice to explain that situation.

MISCELLANEOUS DISCUSSION

Mr. EUSTICE. Mr. Director and gentlemen: In the case of the fuses supplied to the Sullivan Machinery Co., I happen to be entirely familiar with the details of the design and the entire situation, as well as the details of the performance of the fuses manufactured by the Economy Fuse & Manufacturing Co. and supplied to them.

In the early part of the negotiations the Sullivan Machinery Co. applied to the Economy Fuse & Manufacturing Co. for the right to build fuses under patents owned by us, which was denied. Later they submitted tentative sketches of an idea which was being worked upon jointly by the Bureau of Mines of the United States Government and themselves, and asked our cooperation in the matter of furnishing material to them. The type of fuse designed by the Bureau of Mines and submitted finally by the Sullivan Machinery Co. to that Bureau was then submitted to us to manufacture contrary to our instructions to them and contrary to our advice that the design of fuse would not ultimately be satisfactory. Further than that, the fuse itself is not recognized as a cartridge-inclosed fuse. If you put the fuse alongside of any standard form of fuse, I believe many persons would not recognize without seeing the label that that fuse was a cartridge-inclosed fuse. The fuse itself is used in connection with a special type of controller mechanism which is supposed to be explosion proof, naturally for use in mines, particularly coal mines, on coal-cutting machinery. That fuse is used with a comparatively rigid contact on one terminal, and on the other terminal is used within a controller, over the specification of not less than four one-thousandths inch clearance in the rotating member, with simple sliding contact, and it is supposed to carry normally 150 amperes. As fuse builders, our recommendation was that the fuse would not give satisfaction.

The fuses have been in service for perhaps nine months, and a few days ago the first complaint came to us from the Sullivan Machinery Co., stating that the complaint which was beginning to come in from their customers who had purchased machines and were operating them was that the fuse was not carrying its rated capacity, and that the controller connection terminal was becoming loose. Examination shows that the fiber is being heated so disastrously by poor contact, carrying 150 amperes on practically a line contact not more than 1 inch in length; that the fuse is either being destroyed or that the fuse is blowing, due absolutely to contact heating. Furthermore, the fuse supplied to the Sullivan Machinery Co., while bearing the name "Economy," has stated plainly upon the label, by special catalogue numbers, that the fuse was "manufactured for the Sullivan Machinery Co. by the Economy Fuse & Manufacturing Co., of Chicago."

I believe it is not fair, inasmuch as a fuse of that design is not under the specifications of the National Electric Code, to confuse with our regular fuses a fuse which we admit and which we stated before building would not give the desired results, to consider the performance of that fuse as being a fuse subject to the rules and regulations of the National Electric Code and which should be subject to test.

Mr. CUNNINGHAM. I want to explain that I did not know the special type of fuse, and my remark was not intended in any way as a criticism of the Economy Fuse & Manufacturing Co. except in so far as it showed the desire of the user to put in a double-capacity link and putting in copper strips, but not as criticizing the Economy fuse.

Mr. EUSTICE. If I may add one word further. I believe that the letter which Mr. Cunningham read was directed to Mr. Masterson, who is of the Chase-Shawmut Co., and to my certain knowledge I happen to know that the sample of our fuse was placed in the hands of Mr. Masterson, and he, therefore, was familiar with the type of fuse which they evidently got in correspondence with the Sullivan Machinery Co.

Mr. CUNNINGHAM. I have no doubt Mr. Masterson knew about the fuse, but my illustration was only a very vivid example of the danger of overfusing. That was all it was intended for.

Mr. FOOTE. One other point I consider to be erroneous, and which I think should be corrected, was one made by Mr. Sargent when he referred to the fact that 600 volts was not considered in the hearing. He said that every fuse manufacturer should make a complete line of fuses of all sizes. The facts do not bear him out. Some fuse makers only make the ferrule type of fuses; some fuse manufacturers only make knife-blade fuses and some only the plug type; and some make both plug and the other types, and will have approval on one and not approval on the other from the Underwriters' Laboratories. If I am wrong, I will ask to be corrected.

Mr. SARGENT. As far as the manufacturers who built up the industry are concerned, I think they all make the full lines.

Mr. FOOTE. The Connecticut Electrical Manufacturing Co. gives us one example and the "Killark" another.

Another proposition taken up was this: Mr. Merrill suggests there should be a longer time of experience with the fuse before its use, before he should approve it. Does he ask that same thing of the "Killark" or "Sheldon" or 10 or 15 others which have not been on the market three of four months—that have almost no use?

The argument Mr. Merrill made, if it may be called such, and I suppose it may, struck me—I do not mean intentionally—as just a trifle specious. The affidavits which we produced, if they are read and understood from what they say, do not show a basing of the facts which are contained in those documents upon an experience of a few years ago. They were made within the last two or three months when this hearing was arranged for—since May 27. They were made for the special purpose of being presented to this meeting; they were made by men of intelligence who understood what they were making them for, and the statements contained in those documents were not and are not so put as to refer to an experience back two years, and they gave what their experience was, told their experience as to the two questions involved—the question of the refilling of the standard inclosed fuse and the question of the use of the standard inclosed fuse. The sale of the filled type, as we show, is very small in comparison with the nonfilled type sold. The company was young and new in 1912; they had not sold so many fuses. The great majority of those fuses had disappeared from use entirely, so that the great percentage of all the users and insurance inspectors' knowledge comes from the new type, the third type, as he mentioned. And as far as the changes to which he referred are concerned, in the one instance they are due entirely to the manufacturer of parts for the fuses, nothing that the fuse maker (Economy Fuse Co.) has anything to do with, the very small difference in length or thickness; and in the other case the change from brass to phosphor bronze is simply a manufacturing expedient of equally strong devices, not a change in the design in any way; but if it were, it would only tend to the credit of the company if it found anything that could be made better to make it stronger, which is always the policy, and should be the policy, of every progressive concern.

A good deal has been said here by several of the gentlemen who spoke about a matter which I had no idea would enter into this discussion, nor can I in any way see its relevancy; and it is a matter upon which we know quite a considerable amount, and that is that relating to the electrical committee of the National Fire Protection Association. It does not seem to me that this is the place we should be called upon to go into the reasons for the action of the switch and cut-out committee in the making of

their report, nor the dominant factors of that committee in control of the making of that report, nor of the reasons therefor, nor of the questions involved in the submission of contention on our part as to that very thing to the electrical committee, nor our appeal from the electrical committee to the Fire Protection Association. Those things involve questions of fact and not mere statements, as I could state on the opposite side exactly contrary inferences from that deduced by the other gentlemen, and it has been my aim, and I thought that was the purpose of making this hearing formal, to confine ourselves not to unsupported opinion or statement from imagination of what may happen, but from facts that do happen and things that do occur. The question here is whether we have shown that the Economy fuse is no greater fire hazard than any of these other fuses on the market. The extent of use, as against the "Killark," would be 10 to 1 or more; as against the "Sheldon," probably a thousand to one which have been on the market a month or two months, and some of the others more than that. We would have the comparison as to any one rather than to some fuses on the market 10 or 15 or 25 years.

The figures of cost on the board there are so fallacious on their face that it hardly seems necessary to call attention to them. On this side he assumes that the standard fuse is to be refilled at the factory for four years, and I have never heard—I am getting into the realm of opinion myself—of a fuse being returned to the factory even twice for refilling. I simply submit that he had better go forth into the field anywhere and check up any factory-refilled fuse, refilled either by the factory making it or by some other factory. I was going to say that we do not have to compare prices; that is, a mere taking of figures and dealing with something for which we have no data here, in the way of actual figures, except in the few cases I may read to show. But the question is, What do the users say is the reason? If they refill the Economy fuse correctly, due to cheapness, that answers that question as to whether it is more expensive. But if it is a question of comparing with catalogues, then of course the imagination can be used any way one sees fit. Mr. Cunningham refers rather spicily to the evidence we have here, which leads me to tell him the manner in which that evidence was accumulated. In January of this year we sent some 4,000 users of fuses, large and small, this letter:

[Copy.]

ECONOMY FUSE & MANUFACTURING CO.,
KINZIE AND ORLEANS STREETS,
Chicago, January 12, 1915.

The question of the revision of the National Electrical Code on the subject of cartridge fuses will be discussed and finally disposed of by the electrical committee of the National Fire Protection Association at the biennial meeting which will be called at a very early date.

In order that this subject be acted on intelligently, it is important that certain information and the consensus of opinion of a large number of users of fuses be obtained and placed before the Underwriters's committees.

The information requested on the inclosed blank will be tabulated for the purpose mentioned and your individual opinion and reply will be confidential. Your name will not be used in any way.

Will you therefore kindly have your department having jurisdiction over the electrical maintenance of your plant answer the questions on the inclosed blank, with your full opinion, and return to us in the inclosed stamped envelope without delay?

Very truly yours,

ECONOMY FUSE & MANUFACTURING CO.,
A. L. EUSTICE, *President.*

P. S.—If you nave any criticisms on Economy fuses, either on design or performance, as well as any suggestions on the subject of fuses in their relation to fire hazard, please do not hesitate to state in full.

That is the way in which these statements of the users were obtained—not by personal solicitation or seeing any of the individuals in any way. All of those answers came back through the mail in response to that letter, and to the form of questions

inclosed, which were very complete, consisting of some 107 different questions and the answers to them, which you have examined.

There was something said here about the Factory Mutuals. That is another situation which I hoped we would not go into. It was said that the head of the department of inspectors of the Factory Mutuals—a very competent, capable gentleman, who had had long years of experience—had found by allowing the use of the fuse that they were improperly refilled and abused to such a great extent that he could not allow them in use.

Mr. DOWNES. That is not the statement, as the record will show.

Mr. FOOTE. Then I wish you would restate it.

Mr. DOWNES. I only wanted to add that that was one of the chief difficulties with the Mutuals.

Mr. FOOTE. We have submitted 105 cases of where their risks have used the fuse, and, as we found from examination of that evidence, 42 or 43 out of that 105 state and admit that they do refill the standard inclosed fuses on their premises, and quite a number using the Economy fuse say that practice has been done away with, and that, of course, is the keynote of this situation: Does, in practice, the use of the Economy fuse tend to reduce this condition which exists in the abuse of fuses? Here is one of these letters which came in about four days ago (reading):

> I held the report to you to give the fuses a thorough try out. We are certainly pleased with them. They are reliable and do what a fuse is supposed to do, and "Economy" is the right name.
>
> Do you refill standard nonrefillable fuses on your premises? Yes, previous to the present installation, which is now Economy fuses.

There are in this list of customers—call it that or not—statements of hundreds to the effect that they did refill and that they do not now refill [standard fuses] because they use Economy fuses.

Mr. CUNNINGHAM. They do refill?

Mr. FOOTE. They did refill standard nonrefillable fuses, but now they use the Economy, which is a refillable fuse.

But that is important, and a great many of the people who make these statements—the names of the men making the statemments are given—are competent engineers; there are men of no experience, all kinds of persons, and I think a reading of what they say shows the honesty of the statements made. They have been checked or I presume they have been checked. For instance, Mahon Bros. Electric Co., of Port Williams, Ontario, said (reading):

> We consider the Economy fuse a good, practical, efficient, protective device, one which was long looked for. The average electrician in charge of a plant does not stop to consider the danger of using fuses.

Another one said:

> We have been permitted by the Underwriters' Association of the middle department of Philadelphia to use Economy fuses. They would not approve of the use of any other renewable fuse then on the market.
>
> A–14. Ninety per cent of all fuses in our plant are of the renewable type. In my opinion if the committee rules against the renewable fuse it will have a tendency to increase the fire danger, as the temptation to bridge a fuse is much greater. With the renewable fuse it is just as easy to refill it properly as it is to "short" it. Of course this is against the rules, but as I have heard several electricians say, "It is not what you do, it's what you're caught at." How many inspectors will go into a large plant and climb all over the building pulling out fuses to see if a copper strip or a piece of wire is soldered on the back of it?
>
> A–15. Economy fuses have given us as much satisfaction as the standard nonrefillable fuses and should be approved. Nonrefillable fuses when refilled on the premises are subject to improper refilling; that is, reloading with improper material.

I do not intend to go through this, but there has been so much said that I wanted to give a few, because there are some 350 of these letters containing definite answers

and just a few, I think, will tend to enlighten the gentlemen as to what exists in practice. Because a thing is susceptible of a certain thing, it is not a question of what I imagine will happen; it is what does happen, which is the question. (Reading:)

A–1, question C. The price of replacing nonrenewable fuses is objectionable and leads to overfusing to avoid cost and delays.

A–3. A cheap renewal is more likely to be installed than a new expensive fuse; also it reduces tendency to overfusing.

A–6, Q. C. Because it reduces the cost about 75 per cent. If the electrician hasn't a proper renewable fuse he will use a more inferior class of fuse, perhaps copper wire.

A–7, Q. C. Cheaper and more convenient, better motor protection due to less tendency to overfuse or plug circuit.

Without going through all these, the answers would show that the use of the Economy fuse reduces the fuse expense in practically every instance. I can give you a list of the percentages which were found in the printed document submitted to the National Fire Protective Association which has been stated here.

Q. 53. Have Economy fuses actually reduced your fuse maintenance expense?

The total answers in the affirmative were 333, total answering in the negative 16.

Q. 54. Have Economy fuses actually reduced your fuse maintenance expense? How much?

Average percentages stated in all answers 65.78 per cent saving.

That is my answer to the argument here—what the users find, because they are the ones who can figure it out and know what the cost is.

On the question of the number of times the fuse is renewed in practice, there are, aside from numerous ones who give specific answers, one (B. 45) which says he uses Economy 125-ampere fuses at least 50 times. B–48 says, "I kept track of an 80-ampere 600-volt fuse and it has been renewed over 75 times." D–7, which is the Worcester Pressed Steel Co., says he has 426 fuses in use of the Economy style, and he has used 1,400 renewal links.

Also as to the question of actual fires caused by fuses, I think in those answers there are definite references to two cases of Economy fuses, either through improper loading or through some faulty operation, having either burned or caused some little fire, and also in that there are nine specific cases of standard nonrefillable fuses having blown up and caused fire.

I want to add my appreciation to that of Mr. Merrill's as to the efforts of the Bureau, and say that we are very much pleased with the way in which the Bureau has taken hold of this matter and of what has been done.

Mr. CUNNINGHAM. I suppose the oscillograph records and data in reference to those tests are available.

Mr. FOOTE. Those oscillograph records are not under our control.

Mr. CUNNINGHAM. I object to any records being used by the board unless they are readily available to Mr. Downes.

Mr. FOOTE. You do not allow me to finish. The records are under the entire control of Dr. Rosa.

Dr. ROSA. Those records did not come to us from the Economy Fuse & Manufacturing Co. We obtained them ourselves.

Mr. FOOTE. Those are oscillograms the board took. They have nothing to do with the getting of the results of those tests.

Mr. CUNNINGHAM. I understood those tests were made by the Bureau in Chicago and not by the Economy Fuse & Manufacturing Co.

Dr. ROSA. They were made in Chicago and copies supplied to us.

Mr. CUNNINGHAM. You did not take charge of the tests?

Dr. ROSA. We did not see the tests. We have the record and you can see it.

I wish to say on behalf of the Bureau, as I stated at the beginning, we are very anxious to get complete information on both sides of the question. We realize it is a perplexing question and that a good deal can be said on both sides, and it is a question on which different people can very readily reach different conclusions. We would like to get testimony of users of different types of fuses as to their experience, and of course would like to know the names and addresses of the parties who are giving the statements in order that, in so far as practicable, where it is necessary we may confer with them. We have done that in some cases, in some others have visited plants where users have used fuses in considerable numbers or in small numbers, as I have already stated, and conferred with those in charge.

A good deal has been said here in the discussion about the "ignorant public," but not so much has been said about the intelligent users of fuses, and I will say that in our inspection we found a great deal of intelligence in the use of fuses, but we have also seen many examples of fuses improperly used. We shall not come to a conclusion hastily in the matter. We doubtless shall have to spend considerable time on it studying what has been submitted, and perhaps in further experiments and inspection.

We esteem the testimony of users highly, assuming of course that we know the users and know something of the circumstances. I think that we have got a good deal of valuable information already from the personal visits that we have made to places where fuses are being used, both renewable and nonrenewable, and to places where fuses are being renewed on the premises that are not supposed to be.

There have been some statements made that are not in accordance with our experience, in connection with the testing of fuses, and I think very likely that a personal conference between ourselves and some of the manufacturers with regard to tests of fuses and the way they behave would be desirable, in order that we may clear up any outstanding differences or any differences that may result after such conference, where further test is necessary.

We appreciate very much, indeed, the courtesy of those who have spoken to-day, and the good temper that has prevailed. We hope that we shall be able to get sufficient information to clear up the subject and arrive at a correct result.

Certainly nobody here is more anxious that we reach a proper answer to this question than we ourselves are.

The conference will now stand adjourned.

(Thereupon, at 4.30 o'clock p. m., the conference stood adjourned.)

NOTE.—A small amount of informal discussion which occurred at the hearing has been omitted from the foregoing record for the sake of brevity. All such statements have, however, been duly considered and carefully weighed.

REPLY OF ECONOMY FUSE & MANUFACTURING CO. TO STATEMENTS MADE AT HEARING

The Economy Fuse & Manufacturing Co., in submitting its contention with the Underwriters' Laboratories to the Bureau of Standards, did so with the full confidence and belief that here alone, outside of the legally constituted authorities, could be secured a fair hearing on the actual facts and evidence.

It has, therefore, with full knowledge of its rights and the opportunities afforded for the submission of evidence difficult to refute, though erroneous, come open handed to this Bureau, inviting the world to answer it, insisting on nothing, excepting that it be permitted to investigate the evidence of users of these fuses which might be submitted, and agreeing to all the suggestions of the Laboratories whether, in its opinion, fair or not, and it has laid before this Bureau all the results of its laborious investigations in ascertaining the correct answer to the question submitted.

The doors have been thrown wide open and no technical obstacle placed in the way of submitting to the Bureau any evidence, no matter how obtained, which might help answer the question pending, and no objection or restriction has been placed upon the arguments which were desired to be made, whether based upon any definite facts submitted or drawn wholly from the imagination.

It can not be doubted that every effort has been made to secure evidence to meet this company's contention, in view of the action of the insurance organizations and their efforts to make that action appear fair, and considering the campaign of the company's competitors.

And what has been the result?

No evidence of the misuse of Economy fuses has been submitted. No verified statements of the experience in that use from parties who, from observation and experience in their business, might have refuted the evidence submitted by the company, if it exists, have been produced.

The tests of the Economy fuses show equal performance with the tests on standard fuses by the Laboratories and others. On admission the question submitted can find its answer in the negative only in the fact of greater misuse of Economy fuses than that involved in the use of standard fuses, whereas all the evidence emphatically points to the fact, not only of proper use but of a use which reduces the misuse of standard fuses and affords better protection to circuits.

The arguments at the hearing were not directed to a discussion of ascertained facts or to pointing them out. In the case of those of the standard fuse makers they were confined wholly to the unsupported statements of belief and authoritatively announced opinion.

"As who should say, I am Sir Oracle,
And when I ope my lips let no dog bark;"

and to the showing of some so-called tests as to which current values and much other data, for the intelligent consideration of the same, are omitted.

We do not intend to burden the Bureau with an extended answer to the expression of opinion by the standard fuse makers, as they are answered and refuted over and over again in the evidence and printed arguments.

As we understand the argument, it chiefly stresses the construction and supposedly dangerous action of the Economy fuses by reason of lack of filling materials and soldered contacts.

The filling material is constantly referred to as an arc-choking device, when, as a matter of fact, the many oscillograms which the Bureau has will show that the air space in Economy fuses breaks a circuit quicker than any other fuses and never holds an arc, while the contrary is shown of the arc-choking, powder-filled fuses.

As to mechanical contacts, we refer to the fact that a great majority of electrical contacts are not soldered. Witness the screwed and slip friction contacts for lamps, etc., the pressure contacts by spring only on the fuse clips, and screwed-down wire connection on contact block sockets and various electrical devices, and the many other mechanical contacts in the thousands of uses to which electricity is applied.

We also call attention to the fact that amongst the electrical men of intelligence, experience, and learning there are as many who prefer the mechanical contact as there are who prefer the soldered contact.

The dangerous operation referred to is statement merely, and not fact, as we have pointed out in the mass of evidence submitted, and its constant recurrence in the arguments only tends to show how the imagination is and always has been allowed to supply the facts of experience.

Over and over again we are told what will happen, but when investigation is made it is found that it does not happen.

This same tendency to rest secure on their belief that what they imagine is a fact, and that no investigation is necessary to prove it, accounts for the arguments that the

Economy fuse shells will char and fill with molten metal until they become a dangerous device from repeated refilling, when the fact is that the metal is vaporized, does not form any deposit, and the shell is as clean after 100 blows as after 1, and that the shells do not char from the repeated operation of the fuse. Any charring of the Economy shells would be due to causes which would also char a nonrefillable fuse shell. Nonrefillable fuses often remain in a damp place until they are completely rotted away, although apparently in good shape to the casual observer. This can not happen to an Economy fuse because of the ventilation in the air space in the interior and the thickness of the shell.

We wish, again, to emphasize the fact that it is discrimination against the Economy fuses which is the chief point here, and we attach a copy of the patent on an approved Killark fuse, and call attention to lines 110 to 115, page 2, and 35 to 40, page 3, where the readily renewable features of the fuse are especially claimed and set forth. This language is as follows:

> To renew or replace any part or member of the fuse, it is merely necessary to remove end caps 2–2, when the remaining members of the fuse may be readily taken from the casing 1, as will be obvious.
>
> My new fuse may be economically manufactured, and it will be observed that the several parts thereof may be readily assembled and may also be easily and conveniently renewed or replaced.

In what way does this fuse, in the claims made for it, differ in principle from the Economy fuses? Many other standard fuses are as easily renewable and are used as such, as simple investigation shows.

Respectfully submitted.

R. J. Foote, *Counsel.*

STATEMENT ON BEHALF OF MANUFACTURERS OF APPROVED FUSES

1. *Economy Fuses Cause Greater Hazard.*—The manufacturers of the cartridge-inclosed fuses at present listed as standard by the Underwriters' Laboratories maintain that the cartridge fuses manufactured by the Economy Fuse & Manufacturing Co., by reason of their design and plan of use with innumerable refillings, cause a greater fire and accident hazard than the fuses of the cartridge type approved by the Underwriters. The manufacturers of approved fuses contend that the Economy Fuse & Manufacturing Co. has reverted to a type of fuse found fundamentally defective more than 20 years ago, in order to make the fuse conveniently refillable *by the user;* that the fuse is so expensive that it must be refilled many times to pay, and grows rapidly more dangerous at each refilling.

The question here is not whether the future will produce an inclosed fuse of the cartridge type which can safely be refilled. The present approved fuses when not badly strained can be refilled *by the manufacturer,* who has at hand new elements for all strained parts, and are so refilled from time to time. The question is not whether a cartridge fuse can be made which can safely be refilled *by the user,* although such a type has not yet been put out. The question is whether it is as safe to use a fuse without arc-choking material, a type discarded as dangerous for 20 years, and to refill it innumerable times, as to use the approved type of fuses, which is wonderfully efficient as designed, which may be made as dangerous as the Economy fuse by improper refilling, but which is so cheap compared with Economy fuses and so inconvenient to refill that refilling is infrequently resorted to.

We contend—

(1) That the Economy fuse presents an increased fire hazard over the approved fuse when first put up.

(2) That it is much more dangerous when refilled than when new, the danger increasing with each refilling.

(3) That being sold at several times the cost of the approved fuses, with the advice to refill repeatedly, they are purchased only by people who intend to refill them repeatedly, whereas approved fuses are not readily refilled and, in fact, the sizes most used seldom are refilled; consequently the Economy fuse is for the greater part of its life a refilled fuse, and it is accordingly fair to compare the Economy *refilled fuse* with the *approved new fuse*, under which circumstances, *a fortiori*, the Economy fuse is far more dangerous than the approved fuses.

(4) That the fact that the approved and all other fuses are dangerous when refilled improperly by the user only proves that refilling by the user should be forbidden. The Economy fuse is at least equally dangerous when refilled by the user, and the Economy fuse, where used at all, must average to be refilled a great many times to repay its high cost, and is refilled until it *has caused* a fire hazard.

2. *Construction of the Economy Fuse.*—The cartridge fuse of the Economy Fuse & Manufacturing Co. proposed for approval consists of the usual fiber cartridge, inclosed by metal end caps. To make these replaceable readily by the user, the fiber tube is threaded and the end cap is also threaded and fitted with expensive brass parts, which bring the Economy selling price up to 25 cents for a 30-ampere fuse against 9 cents for an approved type fuse. Within the case is the fusible element, consisting usually of a zinc strip and connected to copper terminals. The fuse strip, except for the fact that it has a double rather than a single notch, does not differ materially from the approved fuses. The vital difference is that in order to make the fuse conveniently refillable by the user a vital element is abandoned, namely, the filling of finely divided arc-choking material, which is contained in the fuses approved by the Underwriters and expensive machine work is added, giving no added safety, but a great incentive to repeated refillings.

The method of attachment of the fusible element to the terminal also differs from that adopted by the manufacturers of approved fuses, in that the fusible element is not soldered to the terminal. Soldering must be omitted if ordinary users are to refill, but the omission adds greatly to the danger of the fuse, especially when refilled, owing to the probability of a poor contact, causing the blow to occur at the terminal instead of the central portion of the fuse. This danger increases at each refilling. There are other defects, but those above referred to are most vital.

(1) Omission of arc-choking material to facilitate refilling.

(2) Addition of screw machine and other expensive features, giving no added safety, but increasing cost over approved fuses, so that numerous refillings must be made.

(3) Omission of soldering giving bad contact, particularly when refilled, and inciting to use of a double-fusible element.

(4) Omission of warning to users that fuse case will carbonize after a few blows from extended overload and consequent refilling of fuses with carbonized tubes, until they have actually caught fire or exploded.

3. *Construction of the Approved Fuses.*—The cartridge fuses made by the manufacturers of approved fuses, as above stated, also consist of a fiber casing inclosed by metal end caps. Within the case is the fusible element, consisting usually of a zinc strip and connected to copper terminals. The fusible element, however, unlike that used by the Economy Fuse & Manufacturing Co., is surrounded by a packing of the finely divided material, principally ground plaster of Paris, which 20 years' experience has shown to be the best-known material for choking the electric arc formed on the blowing of a fuse. This material is omitted by the Economy Fuse & Manufacturing Co. to decrease the expense and difficulty of refilling the fuse. Fuse strips used by the standard manufacturers for all high-capacity fuses are deeply notched at the center, whereas the larger capacity Economy fuses have a double notch. It is contended that this double notch removes the necessity of the powdered material, but it is unquestionable that although a fuse strip not surrounded with

finely divided arc-choking material will operate safely a greater percentage of the time when double notched than when single notched, yet the omission of the arc-choking material renders even the double-notched fuse strip certain to operate badly, under conditions when the standard fuses will operate well, as will be more fully pointed out hereafter.

The approved fuses, furthermore, in all cases have the fusible element soldered to the terminal. This also makes for safety and accuracy of operation. The absence of soldering invariably causes danger of an imperfect contact, especially when the fuse is refilled, and an imperfect contact will invariably vary the action of the fuse and endanger its operation.

The approved fuses contain no expensive elements designed to facilitate refilling, and in consequence can be and are sold for less than one-third the price of the Economy fuses on most sizes. The following list, with discounts deducted, is believed to be correct, although it must be remembered that these prices vary somewhat from time to time:

Amperes	Net price Economy refillable	Net price Shawmut approved
30	$0.25	$0.09
60	.50	.126
100	1.00	.324
200	2.00	.72

When it comes to refilling, the approved fuse can not be refilled without much inconvenience and expense, and the refilling is not suggested except for large sizes, and refilling by user is discouraged in every possible way. The ordinary user does not refill. The first cost being less than one-third of the Economy fuse, users wishing to be safe will use new fuses, particularly in small sizes, or, if determined to refill fuses, will generally send them to some maker having conveniences for refilling, because the expense of home refilling will be disproportionate. When refilled at the factory, the maker can supply proper arc-choking material and can replace charred cases or other defective parts, whereas the Economy fuse user must make up for his great initial cost by replacing nothing but the fusible link and doing it himself.

4. *Economy Type of Fuse Discarded 20 Years Ago.*—Prior to 1896 electric fuses had been in common use for many years, and all the elements of the Economy type of fuse were well known. Tubular cases of hard rubber or other nonconducting material, and cases of wood of many different shapes, were frequently used as a protection against fire hazard, and in these cases notched or otherwise weakened strips were placed, which could readily be replaced upon the blowing of the fuse. These fuses were satisfactory until the advent of dynamos of large capacity and increased voltage, when trouble began to develop, until, about 1895 or 1896, it became apparent to the Underwriters that fuses exposed to severe conditions were highly dangerous as then made, and that the inclosure of the fuse in a casing merely increased the danger of a destructive arc. See Electrical Engineer of February 5, 1896, in which the following statement occurs:

> 6. Inclosing a fuse is not safe, as the gases generated upon the fusion of the metal will continue to carry the current in event of a short circuit. See paper read before the American Street Railway Association at Atlanta, Ga., entitled "Destructive arcing of 500-volt fuses."
>
> The permanence of an art, let alone its progress, must depend largely on the reliability of the apparatus employed in it, and in this term must be included the factor of safety. From the very first the fire hazard connected with current distribution has been forced upon the electrical engineer, and, indeed, its consideration still constitutes a live question before electrical bodies, toward which the constant pressure brought upon them by the fire underwriters has contributed

not a little. The fusible cut-out has long been the subject of special attacks, but one of the strongest indictments thus far formulated against its use is the report of William McDevitt, of the Philadelphia Board of Fire Underwriters. In view of the probable effects of the submission of this report we have deemed it well to print it in full in order to place before our readers all the evidence adduced by its author in his sweeping condemnation. That Mr. McDevitt does not stand alone in the position taken by him no one who is familiar with the drift of opinion in electrical circles will deny, and the increasing number of specifications calling for magnetic circuit breakers for circuits carrying above 15 or 20 amperes strongly supports Mr. McDevitt in his contention. The fuse has done good service, but if its day of usefulness is gone for heavy currents, then it must give place to its old competitor, even though its low cost is not the least of the arguments in its favor.

The effect of this situation was that it was seriously proposed to abandon fuses in favor of automatic cut-outs. Under these circumstances, the D. & W. Fuse Co., one of the manufacturers of approved fuses, developed a fuse in which the fusible element was surrounded by a finely divided arc-choking material. This fuse is the basis of all the fuses of the cartridge type approved by the Underwriters. The idea was first patented by Mordey, an Englishman, but the first development of the idea on a large scale was by the D. & W. Fuse Co. Other fuse manufacturers immediately followed this line, and innumerable improvements have since been made, with the result that it is possible to handle any strength of current at 600 volts with one of these fuses, properly made and designed, while the link, not surrounded by a finely divided arc-choking material, has remained and still remains a source of great danger, it being as true now as in 1896 that a fuse link not surrounded by a finely divided arc-choking material is likely to form a destructive arc when it blows, and the continuance of the arc is increased instead of diminished by the existence of the exterior casing.

Notwithstanding the great superiority of a properly designed fuse of the cartridge type filled with an arc-choking material, the demand of the public for cheap fuses was such that it was many years before the Underwriters could force the public to purchase properly made fuses. The difficulty was that the public demanded something cheap rather than something safe, the contest being that which has always existed between the rules of public policy shown by building laws enforcing fireproof construction as compared with the willingness of the public to put up fire traps wherever permitted. During this early period the renewable idea was expressed in patents and frequently embodied in manufacture, but the Underwriters, with their growing experience of the dangers of unsafe construction, were firm, not only for a safe original construction but in their demand for a fuse so made that refilling would be a job requiring more time and patience than the ordinary person would be apt to use.

The public hates to throw away a thing when many of its parts look all right, and in consequence frequent attempts have been made to put out a fuse refillable by the user, but in practice such fuses must revert to the old idea of a link simply surrounded in a case without an arc-choking medium, because users will not mess with a filler. The Economy company has reverted to this type, using parts of great strength to stand the strain necessarily developed by their construction. This great strength of parts is useful in a fuse of the approved type, having an arc choker; but is rather a danger than otherwise in the case of a fuse not surrounded by an arc-choking material, because in that case there is nothing to prevent the metal vapor from holding the current, and if the current holds through the vapor, the stronger the casing the greater the danger that the circuit will stay closed until the apparatus is damaged and the most serious results have occurred.

The Economy fuse is therefore of a defective type, although as well made as is now practicable for that type.

5. *Economy Fuses Fail Under Severe Short-Circuit Tests.*—Both the Underwriters and the manufacturers of approved fuses have tested the fuses made by the Economy company and the results of a few of these tests are annexed.

The danger to apparatus involved in testing a fuse known to be bad in design is so great that it is very difficult to obtain permission to make such tests on 600-volt circuits where the danger to apparatus from any failure is greatest and the likelihood of failure is greatest.

The tests to which we shall refer are as follows:

(First) Statement of October 29, 1914, No. 3408, issued by the Underwriters' Laboratories (Inc.), which reports as follows on the Economy 600-volt fuses, from 61 to 400 amperes:

Failure on short-circuit tests.

This failure of the Economy fuses at 600 volts contrasts with the fact that the approved fuses, with occasional exceptions, readily remedied by change of design will meet the tests imposed without difficulty. The 250-volt line and the smaller capacities of the 600-volt line of the Economy company have not been approved by the underwriters, and we understand that their operation, though better than the large capacities of the 600-volt line, is by no means satisfactory, whereas the standard lines operate almost perfectly. The approved fuses can be improved by change of design to meet much more difficult tests, if the public will stand the expense; but the unfilled fuse can not do better, as its design is fatally defective.

A copy of this is annexed [1] and marked "Underwriters' tests of Economy fuses."

(Second) Tests by D. & W. Fuse Co. In these tests the Economy fuses in most cases exploded. One 100-ampere and one 200-ampere fuse of the 250-volt line operated properly, however, but exploded when reloaded with a sand filler. This refilling was improper, but is not unusual. The fact that these two fuses when filled with sand operated badly is an argument only against any refilled fuse and not against the Economy fuse in particular.

In these tests the D. & W. standard fuses operated properly with one exception, in which a loosely attached end cap blew off.

This paper is attached [1] in full to this brief, being marked "Tests of Economy renewable fuses by D. & W. Fuse Co."

(Third) Tests by Chase-Shawmut Co. The Chase-Shawmut Co. tested the Economy 30, 60, 100, and 200 ampere fuses in connection with the Edison electric light storage battery in Boston. The result of these tests was as follows:

One out of four 30-ampere fuses had a bad explosion at one end on the first trial. One of the fuses which operated well once operated badly as soon as refilled. The other two were not tested on refilling from lack of time.

Of five 60-ampere fuses the operation was substantially satisfactory on the first filling. When tested on refilling, three flashed so as to fire cotton. Two were not refilled.

Of seven 100-ampere fuses tested two operated properly, although with a slight flash, while five operated with flash sufficient to ignite cotton. Refillings, in all cases caused a flash which ignited cotton.

Two 200-ampere Economy fuses tested operated properly on the first test, and improperly when reloaded. A third 200-ampere Economy fuse exploded when first tested.

A 400-ampere Economy fuse also exploded when first tested.

Chase-Shawmut fuses tested at the same time operated properly.

The testing circuit was practically free from inductance, and so did not subject the fuses to the condition which the Economy company finds most dangerous for its fuses. There was a dynamo feeding into the battery and the usual motor and light circuits, but nothing whatever on the testing line except the testing apparatus. The resistance was greater than the underwriters provide, which decreased the severity of the test somewhat.

Details of these tests are hereto attached,[1] marked "Tests of Economy refillable fuses by Chase-Shawmut Co."

6. *Economy Fuse Most Dangerous where Most Used.*—The brief of the Economy Fuse & Manufacturing Co., presented to the National Fire Protection Association April 30, 1915, on page 59, relating to fuse tests, contains the following statement:

The company has developed the fact that under general conditions the physical effects of the operation of a fuse on short-circuit performance depend particularly upon the factors of available capacity, resistance in the circuit, and the induct-

[1] Not included in this report.

ance in the circuit, the latter being by far the most important. In other words, the operation of a fuse on a severe short circuit, as to the venting of fire, bursting of shell, etc., depends upon the relation of the ohmic resistance and inductance; in other words, a circuit with a constant available capacity and with a drop of less than one-half of 1 per cent per 100 amperes, where the impedance ohms are not greater than the resistance ohms, will not cause fire venting or shell bursting on short circuit in the Economy fuse on repeated renewals, and with the same end washers, but with the same capacity and the same or a higher drop per 100 amperes, if the impedance ohms exceed the resistance ohms materially, the destructive effect on any fuse on short-circuit operation varies with the increase in the impedance ohms in the circuit.

The fact is that without inductance in the circuit Economy fuses as well as approved fuses will have a perfect score on severe short-circuit operation, with less than the code requirements as to resistance, on practically an unlimited number of renewals with the same parts. The actual tests have not been extended beyond 50 renewals. Some of the approved so-called nonrenewable fuses show fire venting on the same test conditions. With sufficient inductance in the circuit to cause an Economy fuse to vent fire on the second or third operation with the same end washers, so-called approved nonrenewable fuses will vent fire on the first operation. Given conditions under which any of the approved nonrenewable fuses will not vent fire, an Economy fuse under the same conditions, unless the end washers are injured, will not vent fire on subsequent renewals, and on the replacement of washers on any renewal fire venting will absolutely cease.

In practice no case has ever come to the attention of the company where the operation was severe enough to make necessary the replacement of the washers. It is only on a highly inductive test circuit where the available capacity is many times in excess of that existing in any of the largest industrial installations that the washers ever need to be or should be replaced to prevent fire venting, but for safety the company recommended to users the replacement of washers after severe short-circuit operation.

The substance of this statement is that the fuses are most liable to operate dangerously when used on circuits containing motors, and that the danger is much greater on the refilled fuse than on the new fuse. Now, it is well known that the blowing out of fuses, except on circuits containing motor circuits, is comparatively rare. The principal argument for a refillable fuse is that on motor circuits blow-outs are frequent, and it is unfair to the user to compel him to use new fuses after each blow-out. In view, however, of the admission of the Economy company that these motor circuits are the most dangerous circuits known, it seems to the approved fuse makers obvious that standard fuses are much safer than Economy refillable fuses for such circuits, because the Economy fuse is sent out to be refilled and is refilled until it actually *has become* so bad that it is impossible to get a new element in, which means that it is used until it *has actually caused* a fire danger, while the approved fuses, in the classes under 65 amperes, are never refilled by the maker and are practically unrefillable. The large fuses are not approved by the Underwriters when refilled except by the maker, who has an opportunity to replace all bad materials.

7. *Approved Fuses Operate Safely on Motor Circuits.*—Contrasting with the practical admission that there is danger from Economy fuses when refilled, on motor circuits, which is where they are to be used, and with the fact that the Economy fuse is to be refilled until it *has caused* a fire hazard, we have the fact that the approved fuses operate safely, with great regularity, on motor circuits of the most difficult and dangerous character. The fuses of the D. & W. Fuse Co. are used upon the Interborough System in New York, where the circuit is practically all motors, and where operation must be not only safe but reasonably quiet, and give satisfaction. The Economy fuse might sometimes, when new, operate properly under such conditions; but we can not understand how it is possible to say that the Economy fuse, which is to be used under these dangerous conditions until it has operated badly, can be thought to be as safe as the D. & W. fuse, which is not designed to be used except once, for capacities of 60 amperes and below, and never a second time, until it has been remade by a fuse manufacturer responsible for results, with renewal of every weakened part.

The capacity of the approved fuses to withstand conditions to which motor circuits are exposed, is also shown by tests made by the Chase-Shawmut Co. for another purpose, a statement of which is hereto annexed,[2] marked "Chase-Shawmut tests of approved type of fuses at 600 volts, at main station of Boston Elevated Railway Co."

These tests were made with an oscillograph, for purposes of a suit, and their results were unquestioned. The short circuit was made through two 500 000 circular mils copper cables, one for the feed and one for the return of a length of about 270 feet, giving a resistance on the line of about one-fifth that prescribed by the Underwriters. The capacity of the dynamos running the system at that time from that station was great, and in addition all of the stations were tied in together, so that on the short circuits the temporary rise of the current values on the testing line was met by the assistance of the other stations, and by the reaction of every motor on the line. On some tests the current rose to 17 450 amperes. All the fuses tested as representing the standard line of the Chase-Shawmut Co., operated perfectly except one, which lost an end cap, owing to improper fastening. Fuses tested at the same time, of designs believed to be not quite perfect, operated very badly. We have been unable to submit Economy fuses to this test, because it is so severe that the Boston Elevated Railway Co. refuses to permit it; but it is, after all, a test to which fuses are subject. It is quite true that any Shawmut fuse refilled by the user would probably disappear in smoke under this test, but that is not a reason for holding that fuses refilled by the users should be approved. It is merely a reason for forbidding the use of any fuse for which some, so to speak, licensed fuse maker, is not responsible, both as to making and refilling.

8. *Users will not Discard or Discover Carbonized or Strained Cases or Distorted Caps.*—In view of the statements of the makers of the Economy fuse that their fuses may be refilled 50 times (brief of Apr. 30, 1915, p. 60), it is obvious that users will keep on refilling the fuse until it burns up. This is a serious hazard. A fuse which goes back to the manufacturer is always examined by experts to see whether the case is weakened by carbonization. The user, on the contrary, will note only that the outside of the case is intact, and if he can take off the caps, put in the new link, and replace the caps, he will put his fuse into the circuit with a clear conscience. Accordingly, when the approved fuse blows from long-continued overload, with the result of carbonizing its tube, it is not a fire hazard, because the maker will discard the carbonized tube. When the tube of an Economy fuse is charged, however, it constitutes a grave fire and accident hazard, because it will remain in the circuit until it has burned or exploded.

9. *Refilling of Approved Fuse Difficult for User.*—The refilling of an approved fuse in the sizes 60 amperes and below, which constitute the great majority of fuses used, is so difficult that it can not be economically performed, even by the maker. This is shown by the fact that makers do not attempt it. The fuse sells for 9 cents, or less, and there is no great margin of profit to encourage refilling, as there is in the Economy fuse, selling for 25 cents. The approved fuse of 60 amperes and below has no facilities for the insertion of a new fuse link except by soldering, and it is obvious, if the maker of the fuses can not refill them at a profit, that the user can not. Accordingly, the approved fuses in these small sizes are practically never refilled, while the Economy fuse of the same size is refilled until it has actually burned up and caused a fire hazard.

The refilling of the larger capacity approved fuses can be done at a saving over the use of new fuses, but it is not a work which can be done economically by anyone except the maker, equipped with soldering and other facilities. The rate for refillings made by the maker is so low that only a trivial proportion of the persons using these fuses attempt to make them themselves. The user is not encouraged to refill the fuses himself, and in practice does not do so. Undoubtedly illustrations of users refilling the approved fuses can be given, but the refilling of an approved fuse by the user is the exception, while that of an Economy fuse is a rule.

[2] Not included in this report.

10. *Refilling of Approved Fuse More Readily Detected than that of Economy Fuse.*—The statement of the Economy company that the improper refilling of an Economy fuse can be more readily detected than that of the approved fuse is erroneous.

The user will not accept fuses without an original label of an approved manufacturer for the original fuse, and a proper refilled label for the approved fuse when refilled, if he desires the protection of approved fuses. If the fuse has been refilled by the maker, there will be a refilling label on it. If a user has tried to refill it in practice, the lack of an indicator will readily show to the inspector when an approved fuse has been refilled by the user. Even without the indicator, however, in general, refilling by the user is bound to be apparent, on account of the impossibility of replacing pins and caps without leaving marks of the tools and of the effects of the blow.

The Economy fuse, however, has no indicator, and the fuse must be taken out of its socket and reopened before the inspector can determine whether it has been refilled. It is no easy job to take an Economy fuse apart, after it has been refilled once or twice, without special tools.

The inspector will know, however, before he starts that an Economy fuse has presumably been refilled, because it is sent out to be refilled by the user for dozens of times. The inspector can not, however, determine whether the refilling was proper without taking the fuse apart, carefully examining the interior of the tube to determine the extent of its carbonization, and even then he will not know whether the end fastenings have been strained so that they will readily leak fire. In short, for the approved fuse the inspector has in practice either the certificate of proper refilling, or original make of an approved manufacturer, or else can readily see that the user has been refilling and can order the fuses out. As to the Economy fuse, the inspector knows it is a home-made production and must act himself as an expert fuse maker to determine whether the refilling is proper.

11. *Testing of Fuses by Underwriters Absurd if Refilling by User is Permitted.*—If fuses readily refillable by the user are to be approved, the testing and approval of fuses by the Underwriters' Laboratories is an absurdity. The Economy company states that the inspector can readily determine whether their fuses are properly refilled. This is an admission of the whole case. In the present arrangement most elaborate rules as to the construction of fuses can be made. The fuses of each manufacturer can be subjected to repeated severe tests and improved until they are perfect, within the limits of human error. The label of the manufacturer is then a sufficient guide for all except a fraudulent refilling.

If, however, the user is to be permitted to refill the fuses, then it is impossbile to tell whether the fuse is properly refilled or not except by an examination of each fuse. For the examination of the Underwriters' Laboratories there is to be substituted the supervision of the individual inspector as to the condition of the fuses the particular day he happens to be there. The manufacturers of approved fuses have paid large amounts to the testing laboratories of the Underwriters for testing, because they recognize the value of having careful tests made by an impartial body as a preliminary to approval. The manufacturers of approved fuses will certainly have no occasion to submit or pay for tests on their fuses, as they leave the factory, when the actual fire hazard of the fuse depends solely on how good a fuse maker happens to be in each building insured, and whether his employer is more anxious to have a small fuse bill than to keep down the Underwriters' loss.

In 1904, when the Underwriters called the approved manufacturers together and worked out the N. E. code standard fuses and prescribed dimensions, construction, and test requirements, they began one of the greatest advances in the interests of public safety that has been accomplished in the electrical art. This was possible only through the cooperation of the manufacturers and their continued good faith with the Underwriters. The manufacturers have steadfastly refused to market refillable fuses or any lower grade of fuse than the type duly submitted and approved. This

great advance will be entirely lost if refillable fuses of the Economy type are approved, for what possible interest or responsibility can the manufacturer have in his fuses after they have been refilled at places and by persons to him unknown, which may occur a few hours after leaving his hands? The consequent withdrawal of fuses from the Underwriters' Laboratories by the manufacturers, which is the logical result of approval of refillables, is bound to be followed by withdrawal of other lines, with a diminishing of the moral effect of Underwriters' approval all around. It will be but a short time before "Safety last" will be the electrical-trade slogan.

12. *Summary.*—In the foregoing pages we have given the Bureau of Standards the benefit of our experience in regard to the fire hazard from refillable fuses and the reasons why we consider the underwriters should never approve a fuse which can readily be refilled by the user.

We believe:

(1) That an electric fuse constitutes a grave fire hazard unless properly made.

(2) That owing to the millions of fuses used the matter is of such great importance that no fuses should be approved except such as have been carefully tested by the Underwriters' Laboratories as to design and efficiency when properly made and which bear a label of some maker or refiller responsible for the making or refilling of the fuse.

(3) That the approval of a fuse arranged to be readily refilled by the user is in substance a waiver of all precautions with regard to fuses, because no fuse bears any certificate as to its efficiency, and the individual inspectors are given the duty of passing upon all fuses. Accordingly we think no refillable fuse should be approved by the Underwriters.

(4) Even if any refillable fuse is to be approved, however, the Economy fuse should not be approved.

First. Because it is badly designed, in that it has no arc-choking material and, consequently, will occasionally hold an arc, the greatest fault in any fuse, and will often explode or flash.

Second. Because it is so expensive that it must be refilled many times and is certain to be used until it has actually burned up.

The Bureau is asked by the Economy Fuse & Manufacturing Co. to find that a construction which omits an arc-choking material and is intended to be burned up has proved that it is no more dangerous than the approved type of fuses, which, in most cases, is not refillable at all and in all cases is designed to be refilled only by a maker responsible for results, and which is otherwise refilled only by an impropriety for which the Underwriters should cancel the insurance.

(Signed) GUY CUNNINGHAM,
84 State Street, Boston, Mass.

(For D. & W. Fuse Co., Chase-Shawmut Co., and other approved fuse manufacturers.)

V. LABORATORY TESTS OF FUSES

INTRODUCTION

Three extended series of fuse tests were carried out by the Bureau of Standards under short-circuit conditions of widely varying degrees of severity. The first of these series of tests was made at the laboratories of the Bureau of Standards; the second was made at one of the power plants of the Boston Edison Co. in Boston; and the third was made in a plant of the Commonwealth Edison Co., of Chicago. In these tests the performance of the

Economy fuse was compared with that of six makes of approved cartridge fuses.

1. *Interpretation of Results of Tests.*—In these tests the performance of the fuses was judged by the proportion of failures in a given number of each type tested, and also by the character of the failure that occurred. In interpreting the results six types of fuse failures were recognized, as follows: (*a*) Rupture of fiber cartridge; (*b*) blowing off of cap or blowing out of end; (*c*) mechanical injury to cut-out; (*d*) ignition of cotton placed around the fuse; (*e*) holding of the arc for an appreciable length of time; (*f*) remaking of the circuit after it had once been opened by the fuse. Such phenomena as loud report, failure to indicate, excessive scattering of filler, movement of the caps, scorching of cotton without ignition, while recognized as objectionable, have not been regarded as evidence of failure in the performance of the fuses. A very violent report, however, has been considered a serious objection, because of the possibilities of panics following such violent operation of the fuses. It is also recognized that certain of the types of failures listed above are much more serious than others, and due consideration has been given to this point in judging the relative performance of the fuses.

In the record of the tests presented in the tables which follow, the performance of the fuse is described by the loudness of the report, brightness of the flash, effect on cotton, and by comments covering any special features of the fuse performance. Five degrees of intensity are recognized in the report accompanying the fuse blowing, they being listed as none, very mild, mild, loud, and violent, in the order of their severity. In regard to the flash four degrees of intensity are recognized; namely, very mild, indicating a flash not observed directly but described from its effect on cotton, when the flash was hidden by cotton or asbestos; mild, a visible flash of slight intensity; medium, a fairly bright flash, but not unpleasant to observe; and a brilliant flash, hard on the eyes. The effect on cotton is described as follows: (1) Blown off, cotton blown away from the fuse by the force of the explosion; (2) slightly darkened, a dark discoloration of part of the surface of the cotton; (3) blackened, a definite blackening of a considerable part of the cotton; (4) scorched, a charring of the cotton due to the passage of a flame through it but not causing it to flame or smolder; (5) ignited, cotton smoldering or burning with a flame.

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2. *Equipment Used in Tests.*—The same type of testing equipment was used in all tests. Current was supplied from storage batteries and wattmeters were used ballistically to measure the energy absorbed by the fuse when blown. In many cases also a General Electric 3-vibrator oscillograph was used by which oscillograms were taken recording current, voltage, and time characteristics of the fuse at the time of short circuiting. Complete details of operation will be given in the description of the various tests. The wattmeters were calibrated ballistically before use by maintaining a measured current in the current coils and discharging a condenser through the voltage coils. Voltage and current calibrations were also made on the oscillographs and time was recorded on the films by the use of a 60-cycle alternating current actuating one of the vibrators.

The fuses used in all tests were taken in part from Bureau of Standards stock, part from local jobbers and users of fuses, and the remainder directly from the manufacturers. The Economy fuse cartridges were in some cases refilled many times to determine the deterioration, if any, due to short circuiting.

TESTS AT BUREAU OF STANDARDS

1. *Conditions of the Tests.*—The first series of tests was made in the laboratories of the Bureau of Standards under very mild short-circuit conditions. The limiting current in these tests was from 400 to 800 amperes. The fuses tested under these conditions were all in the 30-ampere 250-volt cartridge, although in many cases the 30-ampere cartridges contained 10 and 20 ampere elements.

The purpose of these tests was to obtain data upon which could be based a fair estimate of the relative fire and accident hazard incurred by the blowing of small ferrule-type fuses with small limiting currents such as would be encountered in the majority of cases in practice, particularly where the supply is through small transformers. The source of energy was a 250-volt storage battery with an 8-hour rating of 50 amperes connected by heavy conductors to the test table in an adjoining room. The circuit was in most cases practically noninductive and gave on short circuit about 800 amperes. A 300-ampere wattmeter used ballistically measured the energy taken by the fuses while blowing. The fuse, after being placed in the cut-out and covered by cotton and asbestos board, was blown by closing the circuit with a large knife switch. The data recorded include the ballistic swing of

the wattmeter, the noise, the flash, and any special phenomena accompanying the operation of the fuse. In Table 2 below, giving the results of these tests, it will be noted that each line is a summary of the results obtained by blowing about 20 fuses. The remarks listed comprise composite statements covering the general average performance of the fuses with the exception of the cases of ignition, the number of which are noted.

2. *Tests on Noninductive Circuit.*—Throughout the entire series of tests in the noninductive circuits no mechanical failures were developed, but in a considerable number of cases ignition of cotton occurred with approved fuses. With fuse No. III ignition occurred at least once with every limiting current, and with each size of fuse up to and including 30 amperes. The No. VI fuses of 20-ampere rating ignited cotton in some instances at the two lower limiting currents. All ignitions with the exception of those occurring with No. VI fuse apparently resulted from the blowing of the indicator. With respect to general operation the Economy fuse performed most satisfactorily. One make of approved fuse, designated as No. V, seemed very erratic in operation, at times showing remarkably good performance and at other times a very inferior one.

TABLE 2

Direct-Current Fuse Tests at Bureau of Standards, Noninductive Circuit

30-AMPERE, 250-VOLT

1. Limiting Current 800 Amperes

Make	Number tested	Watt-second			Report	Average results	
		Max.	Min.	Av.		Flash	Effect on cotton
VII	19	400	256	328	Mild	Very mild.	Slightly darkened.
IV	20	1696	528	726	Medium	Medium	Scorched and blown off.
III	20	504	352	391	Mild	Mild	Scorched; three ignited.
VI	20	684	176	234	Very mild.	do	Scorched at indicator.
Economy	19	168	144	154	Mild	do	None, or slightly darkened.

2. Limiting Current 600 Amperes

VII	20	408	222	290	None	Very mild.	Slightly darkened.
IV	19	904	112	567	Mild	Mild	Scorched.
III	20	400	264	321	None	do	Scorched; three ignited.
VI	20	448	112	173	Mild	do	Scorched at indicator.
Economy	20	128	88	102	do	do	Slightly darkened.

3. Limiting Current 400 Amperes

VII	20	304	0	252	None	None	None.
IV	20	1120	48	570	Mild	Medium	Scorched.
III	20	418	248	324	do	Mild	Scorched; three ignited.
VI	20	408	112	208	do	do	Scorched.
Economy	20	192	56	94	do	do	None, or slightly darkened.

TABLE 2—Continued

Direct-Current Fuse Tests at Bureau of Standards, Noninductive Circuit—Continued

20-AMPERE, 250-VOLT

1. Limiting Current 800 Amperes

Make	Number tested	Watt-second			Report	Average results	
		Max.	Min.	Av.		Flash	Effect on cotton
VII	20	264	128	182	Mild	None	None.
IV	20	2304	440	773	Medium	Medium	Scorched and blown off.
III	20	304	184	238	None	Mild	Scorched; one ignited.
VI	20	544	112	242	Very mild	do	Scorched at indicator.
Economy	25	192	144	167	Mild	do	None, or slightly darkened.

2. Limiting Current 600 Amperes

VII	20	408	324	290	None	Very mild	Slightly darkened.
IV	20	1384	64	726	Medium	Medium	Scorched.
III	20	544	184	261	Mild	Mild	Scorched; four ignited.
VI	20	288	80	139	Very mild	do	Scorched; one ignited.
Economy	20	176	96	125	Mild	do	None, or slightly darkened.

3. Limiting Current 400 Amperes

VII	20	240	112	166	Very mild	None	None.
IV	20	1008	40	492	Mild	Mild	Scorched and blown off.
III	20	304	128	222	Very mild	do	Scorched; three ignited.
VI	20	408	48	170	Mild	do	Scorched; one ignited.
Economy	20	310	80	133	do	do	Slightly darkened.

10-AMPERE, 250-VOLT

1. Limiting Current 800 Amperes

VII	20	48	32	42	Mild	Mild	Blackened.
IV	20	112	80	96	do	do	Scorched.
III	20	144	112	132	None	do	Scorched; one ignited.
VI	20	80	48	63	Very mild	do	Scorched at indicator.
Economy	19	128	88	102	Mild	do	None.
V	34	1344	144	736	Medium	Bright	Scorched or blackened.

2. Limiting Current 600 Amperes

VII	20	64	16	29	Mild	Mild	Slightly darkened.
IV	20	104	64	70	do	do	Slightly scorched.
III	20	144	64	87	do	do	Scorched; three ignited.
VI	20	48	24	32	Very mild	do	Scorched at indicator.
Economy	20	144	48	90	Mild	do	None, or slightly darkened.

3. Limiting Current 400 Amperes

VII	19	24	8	18	Mild	Mild	Blackened.
IV	20	1024	32	97	do	do	Scorched and blown off.
III	20	96	32	52	None	do	Scorched; six ignited.
VI	20	32	24	24	Mild	do	Scorched at indicator.
Economy	20	128	64	90	do	do	Slightly darkened.

The values of energy recorded were obtained with the wattmeter used ballistically, as described above. With the exception of a very few instances, the measured amount of energy on noninductive circuits was consistently uniform, increasing with an increase in rating or limiting current value. In the case of the

largest size fuse element in the 30-ampere cartridge the energy taken by the Economy fuse is markedly less than in the case of the other fuses. It is a very interesting fact, which may be noted here, that in all approved fuses tested, with possibly one exception, there was a much higher percentage of cases of ignition of cotton on these very low-limiting currents than occurred in the later tests made in Boston and Chicago, where the limiting current was from 10 to 12 times as large. In all other respects, however, the fuse performance on these low-limiting currents was much milder than that observed under the more severe short-circuit conditions. The difference in the effect on cotton is possibly explainable on two grounds: First, that under the more severe short-circuit conditions, the explosion being more energetic, the rush of air may cause the cotton to move away from those portions of the cartridge from which the flame would come an instant later; and second, it was noted that when the fuses were blown under the mild short-circuit conditions the fuses were in general comparatively dry immediately after being blown. When, however, the fuses were blown under severe short-circuit conditions, those fuses having powdered filler were more or less wet on the outside, due to the fact that the high temperature developed inside the fuse had liberated large amounts of water of crystallization from the filler, and this would naturally tend to prevent ignition or extinguish any flame. In fact, this is one of the useful functions of the powdered filler in many, if not all, approved fuses. This latter explanation is strongly supported by the fact that the Economy fuse, which contains no filler, gave a very satisfactory performance with no ignition of cotton under the low-limiting current, but gave a relatively poor performance when the limiting currents were large.

3. *Tests on Inductive Circuit.*—Although not specified in the National Electrical Code, the influence of a series inductance upon the performance of fuses on short circuit was found to be very great. A few tests with a highly inductive circuit were made with low-limiting currents at the Bureau of Standards, and in some later tests at Boston with heavy limiting currents circuits having several different values of inductance were used. In the tests at the Bureau the limiting current was approximately 800 amperes, with an added inductance of 0.004 henry, which is equivalent to about 1.5 ohms at 60 cycles. The inductance consisted of a large coil of insulated conductor of large cross section wound

around a straight laminated iron core so proportioned as to insure against saturation.

A comparison at the Bureau of Economy fuses with approved fuses under these conditions gave very different results from those obtained on a noninductive circuit. Whereas in the former case the Economy fuses behaved as well as any of the approved fuses and somewhat better than certain of the latter, when tested on a circuit of high inductance the Economy fuse was decidedly inferior to all of the approved fuses. One make of approved fuse gave perfect operation in every case; three makes gave somewhat inferior performance to that on noninductive circuit, but nevertheless the results were on the whole quite satisfactory. The Economy fuses, however, behaved very badly on inductive circuits, and some exploded with very violent reports. From these tests it is clear that the violence of the fuse operation is much greater on inductive circuits than on noninductive circuits, and, what is of particular interest here, the deleterious effect of inductance is much greater in the Economy fuse than it is in the case of fuses of the approved type. The explanation for this is probably the same as that given above for the effect of very heavy short-circuit current.

4. *Summary of Results of Tests on Low-Limiting Currents.*—In general, the results under these very mild short-circuit conditions were favorable to the Economy fuse except where relatively high inductance existed in the circuit. It was found that the energy consumption of the Economy fuse was in general much smaller than that of approved fuses, indicating a quicker operation, which was later verified under more severe short-circuit conditions by means of oscillograms. On circuits of high inductance, however, on which the ratio of the 60-cycle reactance to the resistance was between 3 and 5 to 1, the performance of the Economy fuse was quite unsatisfactory, even on these small limiting currents, a considerable proportion of the cartridges being exploded in the test. In the case of direct-current circuits, in which motors and magnetic coils and simlar inductive apparatus are used, and also in case of supply lines run in separate iron conduits, as is sometimes done, these high inductances might often be encountered in practice, so that the failures of the Economy fuses on these mild short-circuit tests might very reasonably be taken as an index to their performance in many cases under service conditions.

TESTS ON 250-VOLT FUSES IN BOSTON, MASS.

A second series of tests made by the Bureau of Standards was carried out at one of the plants of the Edison Electric Illuminating Co., of Boston, these tests being made on 250-volt fuses under the short-circuit conditions prescribed by Underwriters' Laboratories. In these tests the performance of the Economy fuses was compared with that of six different makes of approved fuses.

1. *Circuit Conditions During Tests.*—These tests were made under three different circuit conditions, in the first two of which the limiting current was about 10 000 amperes, the difference being that under the first circuit condition the inductance of the circuit was 0.186 millihenry, whereas in the second circuit condition it was reduced to a minimum value by placing the leads as close together as practicable, the inductance in this case being 0.11 millihenry. In the third circuit condition the limiting current was reduced to about 5500 amperes, the circuit having an inductance of 0.166 millihenry. In these three series of tests all fuses were tested with only a single fuse of 250-volt rating in the circuit. A series of tests was also made under the second circuit condition mentioned above in which two fuses were placed in series on 250 volts. These tests were made because of the fact that in actual practice the great majority of fuses which blow on short circuit operate with two fuses in series. In this series all fuses, including the Economy fuse, behaved in a perfectly satisfactory manner.

2. *Rating of Fuses.*—Prior to the tests the fuses of all the different sizes and makes, of the combined manufacturers' and jobbers' stocks, were sampled and a representative number taken at random for rating. These were rated in the laboratory of the Edison Electric Illuminating Co., of Boston, the different makes being rated under identical conditions closely approximating those employed by the Underwriters' Laboratories. In these tests, which were made with currents exceeding the rated currents given on the cartridge labels by 10 per cent, a portion of both approved and Economy fuses failed.

The fuse failures on rating tests are listed in Table 3. Each line represents a particular fuse failure under the conditions indicated at the heads of the columns. The first three headings are self-explanatory. The fourth column headed, "Minutes before blowing," indicates the length of time the fuse was subjected to the current flow before opening the circuit. Copper-constantan thermocouples were utilized to obtain the temperature variations at

the surface of the fiber shells of the fuses, they being placed, in general, upon alternate fuses in a group under test. Approximately 58 per cent of fuse failures occurred with no thermocouples present. The voltage of the source of energy supply is given in the next column, the higher value indicating that the commercial lighting mains were used and the lower values indicating that low-voltage storage batteries were used. Room temperatures in the following column were given to show that normal conditions existed. One 30-ampere, make II fuse heated excessively and gave off smoke before failure. The 100-ampere make IV fuse failed to maintain the circuit until the temperature became constant. In general, however, so long a time was required for failure, being in most cases from one to three hours, that the performance of the fuses was considered satisfactory, particularly since a large proportion did not fail at all, so that the short-circuit tests were proceeded with.

In the summary sheet, Table 4, a comparison of the approved fuses as a whole with those of the Economy company shows but a slight difference in percentage of failures.

3. *Results of Short-Circuit Tests on 250-Volt Fuses.*—The results of the short-circuit tests are presented in Table 5 below, and a summary is given in Table 6. In addition to these tables reference is made to the oscillograms reproduced herewith, which will be discussed later. Referring to the summarizing Table 6, the first column gives the make of fuse, which in all except the Economy fuse is referred to by number only; the second column gives the circuit condition described above, and also in the footnote accompanying the table. The third column, headed "failure," shows in the vertical columns the type of the failure, A, B, C, etc., listed above, and the horizontal rows give the number of each type of failure under each circuit condition. The fourth column gives the total number of each make of fuse tested under each circuit condition. The next column gives the per cent of each make of fuse which failed under each circuit condition, and the last column gives the "percentage of failures." A distinction is here made between "per cent failed" and "per cent of failures," the former meaning the percentage of the number of fuses tested which actually developed some form of failure. In many cases, however, a single fuse developed two or more types of failure, all of which are charged against the fuse, and the sum of all such failures constitutes the number of "failures" used in determining

the percentage in the last column. Owing to the fact that in some cases a single fuse developed two or more types of failure, it will be seen from the last column that the percentage of failures frequently exceeds 100 per cent. In these tables, under the col umn headed "failure," the spaces designated by "0" indicate that fuses were tested under this condition but no failures resulted thereunder. For example, referring to Table 6, which summarizes the results on the ferrule types of fuses, it will be seen that with fuse number I there were no failures throughout the entire series of tests, although 10 were tested under the first-circuit condition and 4 under the second-circuit condition. With fuse number II 15 were tested under the first-circuit condition and 7 under the second-circuit condition. Referring to the column headed "failure," it will be seen that of the 15 tested under the first-circuit condition there were no failures of the A type, namely, explosion of the cartridge, whereas there were failures of the B type, namely, blowing off of cap or blowing out of end; 7 failures of the C type, and 7 of the D type, making a total of 26 failures in all. The per cent column shows that 100 per cent of the fuses tested failed; and owing to the fact that there were 26 failures of all types, the per cent of failures is 173. Number II was the worst of the approved fuses, and it will also be seen that this fuse in the ferrule type was inferior to the Economy fuse, which ranked second in the list. Fuse number VI, as well as number I, developed no failures; and numbers III and IV and V are much superior to either number II or the Economy.

Referring to the second half of Table 6, which summarizes the tests on the knife-blade types of fuses, it will be seen that fuses numbers I, III, IV, and VI showed no failures whatever. Number II showed a single failure of the D type, namely, ignition of cotton; and number V showed one similar failure on the first circuit condition and another on the second circuit condition. It appears, therefore, that the approved fuses in the knife-blade sizes gave a remarkably good performance. The Economy fuse, however, showed a large number of failures, 38 per cent of all cartridges blown having failed under the first circuit condition and 33 per cent under the second circuit condition. For the most part these failures are seen to be of the D type, namely, ignition of cotton, although there was one case of exploded cartridge and two in which the cap blew off, giving 43 per cent of failures under the

first circuit condition and 38 per cent under the second circuit condition. The details of these tests can best be had by an examination of Table 5.

From the foregoing discussion it will be seen that in these 250-volt tests under both the first and second circuit conditions the performance of the Economy fuses in the knife-blade types was in all cases decidedly inferior to that of the approved fuses. In the ferrule type the Economy fuses were inferior to five makes of the approved fuses and definitely superior to one of the six makes. Under the third circuit condition, in which the limiting current was reduced to about 5500 amperes, the tables show that all fuses, including the Economy, behaved in a satisfactory manner, except that in a few cases the blowing of one of the approved makes of fuses was accompanied by rather loud reports. A few fuses were blown with two in series on 250 volts. These are not put in separate tables, but are designated in Table 5 by the letters A and B. Where two fuses are blown in series, they are lettered consecutively, the first having the letter A prefixed and the other the letter B; and in the remarks column the fuse with which it was in series is explicitly stated. Thus, for example, in "Second-circuit condition" section of Table 5, under D. & W. fuses, it will be seen that the first pair of fuses designated as A and B are A–404 and B–405; and the remarks show further that these two were in series with each other. In every case, both with the approved fuses and Economy fuses, the operation was entirely satisfactory when two fuses were in series.

TABLE 3

Failure of 250-Volt Cartridge Fuses on Rating Test at Testing Laboratories of the Edison Electric Illuminating Co. of Boston

Date	Current	Make of fuse	Minutes before blowing	Thermo-couple on fuse	Voltage of circuit	Average temperature of room
1915	Amp.					°F
Sept. 7	110	IV	78	Yes	110	78
7	110	IV	90	Yes	110	78
7	110	IV	100	Yes	110	78
7	220	IV	75	Yes	2	78
7	220	IV	85	Yes	2	78
7	220	IV	98	Yes	2	78
7	220	IV	195	Yes	2	78
8	33	V	20	No	110	81
8	33	V	35	No	110	81
8	33	V	45	No	110	81
8	33	V	95	No	110	81
8	33	IV	105	No	110	81
8	33	IV	145	No	110	81
8	33	II	175	No	110	81
8	220	III	215	Yes	110	81
8	33	III	15	Yes	110	81
8	660	I	75	No	4	81
8	660	I	108	No	4	81
8	33	Economy	145	No	110	81
8	440	IV	20	No	4	81
9	660	V	120	No	4	88
9	660	V	235	Yes	4	88
9	660	Economy	365	No	4	88
9	660	V	365	No	4	88
9	660	V	400	No	4	88
9	660	Economy	420	No	4	88
9	660	Economy	425	No	4	88
9	110	IV	35	Yes	4	88
9	110	IV	60	Yes	4	88
9	110	IV	102	Yes	4	88
9	110	IV	107	Yes	4	88
9	110	IV	152	No	4	88
9	110	IV	157	No	4	88
9	110	IV	157	No	4	88
9	110	IV	157	No	4	88
9	220	IV	70	No	110	87
9	220	IV	125	No	110	87
9	220	IV	190	Yes	110	87
10	660	VI	95	Yes	4	87
10	660	VI	155	Yes	4	87

TABLE 4

Summary of 250-Volt Rating Tests, Boston, Mass.

Make of fuse	Ampere rating					Performance	
	30	100	200	400	600	Total failures	Per cent failures
Economy	6	12	6	5	4	4	12.1
IV	8	17	17	7	14	21	33.3
V	11	6	6	5	5	8	24.2
VI	6	6	6	6	15	2	5.1
II	8	5	6	5	7	1	3.2
III	7	8	8	6	6	2	5.7
I	6	6	5	6	8	2	6.4

Total of all approved fuses failed, 36; total of all approved fuses rated, 232; per cent failures of all approved fuses, 15.5.

TABLE 5

Record of Fuse Short-Circuit Test, Boston, Mass., September, 1915

FIRST CIRCUIT CONDITION, 250 VOLTS

No. I Fuses

Fuse No.	Film No.	Stock [a]	Fuse rating	Kw-sec.	Behavior			Remarks
					Noise	Flash	Cotton	
97	.....	R	30	1.8	Medium..	None.....	Scorched at indicator and blown away.....	Vented at both ends.
98	.....	R	30	1.8	...do.....	...do.....	.....do.....	Do.
99	.....	R	30	1.8	...do.....	...do.....	Scorched at indicator.....	Do.
100	.....	R	30	1.8	...do.....	Mild.....	.....do.....	Do.
101	.....	R	30	2.0	...do.....	Medium..	.....do.....	Do.
120	.....	.....	30	2.0	...do.....	...do.....	Scorched.....	Do.
121	.....	.....	30	1.8	Lig ht.....	Mild.....	.....do.....	Do.
122	.....	.....	30	1.7	...do.....	...do.....	.....do.....	
128	5-F	.....	30	2.0	...do.....	None.....	Blackened.....	Do.
129	.....	R	30	1.7	...do.....	...do.....	.....do.....	Do.
43	1-C	R	100	6.4	Medium..	Mild.....	Scorched.....	Do.
44	2-C	R	100	7.6	...do.....	...do.....	.....do.....	Vented at both ends. Did not indicate.
45	5-C	.....	100	7.3	...do.....	Medium..	.....do.....	Do.
46	1-D	R	100	7.0	...do.....	...do.....	.....do.....	Vented at both ends.
47	2-D	.....	100	8.1	...do.....	...do.....	.....do.....	Do.
48	.....	.....	100	7.1	...do.....	...do.....	.....do.....	Do.
158	1-I	R	100	8.4	...do.....	Bright....	Scorched at both ends; blackened at indicator..	Do.
159	2-I	.....	100	7.7	Light.....	Mild.....	Blackened and scorched.....	Vented at both ends. Did not indicate.
37	.....	R	200	14.3	Medium..	Medium..	Blackened.....	Filler blown out at both ends.
38	5-A	R	200	14.2	Loud	...do.....	.....do.....	Vented at both ends. Did not indicate.
39	1-B	.....	200	14.6	...do.....	...do.....	.....do.....	Filler blown out at both ends.
40	2-B	R	200	14.2	...do.....	...do.....	.....do.....	Filler blown out at both ends. Did not indicate.
41	.....	.....	200	13.6	Medium..	Mild.....	Scorched.....	Filler blown out at both ends.
150	.....	.....	200	14.3	Very light.	...do.....	Blackened.....	Vented at one end.
42	.....	R	200	14.1	Medium..	...do.....	Scorched	Filler blown out at both ends.
151	.....	R	200	14.5	Loud.....	Bright....	Blown away.....	Much filler blown out at both ends.
67	.....	R	400	30.3	...do.....	Medium..	Blackened and blown away.....	Vented at both ends. Did not indicate.
68	5-D	R	400	24.9	...do.....	Mild.....	.....do.....	Filler blown out at both ends. Did not indicate.
69	.....	R	400	23.4	...do.....	...do.....	.....do.....	Filler blown out at both ends.
70	.....	R	400	24.7	...do.....	Medium..	.....do.....	Do.
167	.....	.....	400	29.8	Medium..	...do.....	Blown away.....	Filler blown out at both ends. Did not indicate.
168	.....	.....	400	31.3	...do.....	Bright....	.....do.....	Filler blown out at both ends.
223	2-O	R	400	30.5	...do.....	Mild.....	Blackened at both ends and blown away.....	Filler blown out at both ends. Did not indicate.
224	.....	.....	400	34.0	Very light.	Medium..	.....do.....	Do.
184	4-K	.....	600	40.1	Medium..	...do.....	Blackened.....	Do.
185	.....	.....	600	38.7	Light.....	...do.....	Scorched at one cap.....	Vented at one end.
186	.....	.....	600	43.4	...do.....	...do.....	Blackened.....	Vented at both ends.

No. II Fuses

206A'	.....	.....	30	8.5	None	Bright	Ignited	
82	.....	J	30	3.0	Loud	do	Blown away	Hole blown in center of indicator end.
83	.....	J	30	2.3	do	do	do	Indicator end cap blown off. Pin blown out of other end.
84	.....	J	30	2.7	do	do	do	Indicator end cap blown off.
86	.....	.....	30	2.4	do	do	do	Indicator end cap blown off. Cartridge blown out of clips.
85	.....	J	30	2.6	do	do	do	Indicator end cap blown off.
123	.....	J	30	2.6	do	Medium	Scorched	Indicator end cap blown off. Bent clips.
124	.....	J	30	2.7	do	do	Blackened	Indicator end cap blown off.
125	.....	J	30	2.7	do	do	Blackened and blown away	Indicator end cap blown off. Bent clips.
227	.....	.....	60	10.9	do	Very bright	Ignited	Do.
228	1-P	J	60	16.8	do	do	do	Indicator end cap blown through cage. Bent clips.
229	2-P	J	60	4.1	Light	Medium	do	
230	3-P	J	60	4.7	Loud	do	do	Indicator end cap blown off. Cartridge blown out of cut-out. Bent clip.
231	.....	J	60	4.3	Violent	do	do	Do.
232	.....	.....	60	4.2	do	do	do	Do.
164	3-I	R	100	8.4	Light	None	Blackened	
165	4-I	R	100	9.0	do	Medium	Blackened and scorched at indicator	Vented at both ends.
166	5-I	R	100	8.4	Medium	Very bright	Scorched at cap and indicator	Vented at one end.
152	.....	J & R	200	18.7	do	Medium	Scorched	Do.
153	.....	J & R	200	17.6	do	Bright	do	Vented at both ends. Metal blown out along blade at one end.
225	3-0	J	400	42.5	do	Mild	Blackened at both ends and scorched at indicator	
226	.....	J	400	36.2	do	do	do	Metal blown out along blade. Metal blown on cotton.
187	5-K	J & R	600	70.0	Light	None	Blackened	Filler blown out at both ends.
188	.....	J	600	70.6	Medium	do	Blackened at end and scorched at indicator	Do.
189	.....	J & R	600	68.5	Light	do	Blackened	

No. III Fuses

92	.....	.....	30	2.3	Medium	None	Blackened at indicator	
93	.....	R	30	1.6	Light	do	do	
94	.....	R	30	1.9	do	do	Scorched at indicator	
95	.....	R	30	1.6	do	do	Blackened at indicator	
96	.....	.....	30	1.3	do	do	Scorched at indicator	
135	5-G	.....	30	1.6	do	Mild	Blackened	
136	.....	.....	30	1.6	Medium	Medium	Ignited	
54	4-B	J	100	7.2	do	do	Scorched at indicator	Vented and filler blown out at both ends.
55	5-B	.....	100	6.6	do	Mild	do	Do.

[a] In this column the symbol R means that the fuse was rated. The symbol J means that the fuse was taken from jobbers' stock. Where no symbol is given, the fuse was supplied by the manufacturer.

TABLE 5—Continued

Record of Fuse Short-Circuit Test, Boston, Mass., September, 1915—Continued

FIRST CIRCUIT CONDITION, 250 VOLTS—Continued

No. III Fuses—Continued

Fuse No.	Film No.	Stock	Fuse rating	Kw-sec.	Behavior			Remarks
					Noise	Flash	Cotton	
56			100	6.9	Medium	Medium	Scorched at indicator	Vented.
57		J	100	7.8	do	do	Blown away at one end	Do.
58			100	6.1	do	Mild	do	Do.
177		R	100	6.4	Light	do	Scorched at indicator and blown away at one end	Do.
178		R	100	6.9	Medium	Medium	do	Vented and filler blown out at both ends.
179			100	8.4	do	do	Scorched at indicator and blown away at both ends.	Do.
180		R	100	6.3	Light	do	Scorched at indicator	
181	4-J	J & R	100	8.2	Medium	do	Scorched at indicator and one cap	
182	5-J		100	7.6	do	Bright	Scorched at indicator and both ends	
49	3-B		200	17.6	do	Mild	Scorched at indicator	
50			200	17.4	Light	do	Scorched at indicator and blown away	One cap started 3/32 inch. Vented at both ends.
51		R	200	22.4	Medium	do	Scorched at indicator	Vented at one end.
52		R	200	16.6	do	do	do	Vented at both ends.
53		J & R	200	20.2	do	do	do	Do.
171		J	400	47.8	do	Medium	do	Do.
172			400	39.2	None	None	Blackened at indicator	Vented at one end.
219	5-N	R	400	47.8	Light	Bright	Scorched at indicator	Vented at both ends.
220		R	400	58.5	Loud	do	Blown away	Filler blown out at one end.
193	2-L	J	600	79.5	Light	None	Blackened and moistened	Vented at one end. Did not indicate.
194		J	600	53.7	do	do	do	
195			600	72.8	do	do	do	

No. IV Fuses

102			30	2.6	Medium	Medium	Scorched at indicator and blown away	Vented at both ends. One cap started 1/8 inch. Filler blown out at indicator.
103			30	2.3	Loud	None	Blackened and blown away	Vented at one end. Filler blown out at indicator.
104			30	2.6	do	Medium	Blown away	One cap started. Filler blown out at indicator.
105			30	1.7	do	Bright	Blackened	Filler blown out at indicator.
106			30	2.6	do	do	Blown away	Indicator screen and much filler blown out.
130			30	2.6	Medium	Mild	do	Indicator screen and much filler blown out. Vented at one end.

131	.....	.....	30	2.4	...do.....	...do.....	Scorched.....	One cap started 1/16 inch, bending pin.
132	.....	.....	30	2.1	...do.....	None.....	Ignited, apparently from indicator.....	
175	1-J	J	100	11.7	None.....	...do.....	Scorched at indicator and one cap.....	
176	2-J	.....	100	11.1	...do.....	...do.....	.....do.....	
154	.....	.....	200	19.1	...do.....	...do.....	No effect.....	
155	.....	.....	200	19.5	...do.....	...do.....	.....do.....	
73	.....	.....	400	38.9	...do.....	...do.....	.....do.....	Cartridge moist.
74	.....	.....	400	35.9	...do.....	...do.....	.....do.....	Do.
75	.....	.....	400	35.6	...do.....	...do.....	.....do.....	Do.
76	.....	.....	400	38.2	Light.....	...do.....	.....do.....	Do.
169	.....	J	400	37.4	None.....	...do.....	Blackened.....	Vented at one end.
170	.....	.....	400	36.7	...do.....	...do.....	.....do.....	Vented at one end. Cartridge moist.
215	2-N	R	400	35.3	Light.....	...do.....	Slightly blackened.....	Cartridge moist.
216	3-N	.....	400	34.7	...do.....	...do.....	Slightly scorched.....	Do.
190	1-L	J	600	69.0	...do.....	...do.....	Blackened.....	Vented at both ends.
191	.....	.....	600	87.2	...do.....	...do.....	.....do.....	Vented at one end.
192	.....	J	600	108.0	...do.....	...do.....	.....do.....	Vented at both ends.

No. V Fuses

87	.....	.....	30	1.7	None.....	None.....	Scorched at indicator.....	
88	.....	.....	30	2.6	...do.....	Mild.....	.....do.....	
89	.....	.....	30	2.3	...do.....	None.....	Blackened at indicator.....	
90	.....	.....	30	2.3	...do.....	...do.....	Blackened at indicator and blown away.....	
91	.....	.....	30	1.9	...do.....	...do.....	Blackened at indicator.....	Solder melted at one end.
133	1-G	R	30	2.1	Medium..	Mild.....	Ignited.....	
134	2-G	.....	30	1.8	...do.....	...do.....	.....do.....	Did not indicate.
233	5-P	.....	60	5.3	Light.....	Medium..	Blackened.....	None.
234	.....	.....	60	5.4	...do.....	Mild.....	Scorched through at indicator.....	Vented at both ends.
235	.....	.....	60	4.7	...do.....	...do.....	Scorched at indicator.....	Do.
236	.....	.....	60	4.9	Medium..	None.....	Ignited.....	Do.
237	.....	.....	60	4.7	...do.....	Medium..	Scorched.....	Do.
238	.....	.....	60	4.1	...do.....	...do.....	Scorched and blown away.....	Solder melted at one end.
13	.....	J	100	7.9	...do.....	Bright.....	Scorched at indicator and both ends.....	Vented at one end and under cap.
14	.....	J	100	8.4	Light.....	Mild.....	.....do.....	Vented at screw in cap.
15	.....	.....	100	8.2	...do.....	...do.....	.....do.....	Vented at one end and screw in cap.
16	.....	.....	100	7.7	...do.....	...do.....	.....do.....	Vented at screw in cap.
17	.....	J	100	9.1	...do.....	Medium..	.....do.....	Do.
18	.....	J	100	8.7	Loud.....	Mild.....	.....do.....	Vented at one end and screw in cap.
140	3-H	J & R	100	8.6	Medium..	...do.....	Scorched at indicator.....	Do.
141	4-H	J	100	8.8	...do.....	Bright.....	Blackened.....	Do.
142	5-H	R	100	7.9	Light.....	None.....	Scorched.....	Vented along one blade and screw in cap.
19	.....	J	200	18.2	...do.....	Mild.....	Scorched at indicator and both ends.....	Vented at one end.
20	.....	.....	200	17.2	Medium..	...do.....	.....do.....	Do.
21	.....	.....	200	18.2	Light.....	...do.....	Scorched.....	Do.
22	.....	R & J	200	18.2	...do.....	...do.....	.....do.....	Do.
23	.....	R & J	200	18.7	Loud.....	Medium..	.....do.....	Do.
24	.....	R	200	17.4	...do.....	...do.....	.....do.....	Do.
148	.....	J	200	18.8	None.....	None.....	Scorched at indicator and screw in cap.....	Do.

TABLE 5—Continued

Record of Fuse Short-Circuit Test, Boston, Mass., September, 1915—Continued

FIRST CIRCUIT CONDITION, 250 VOLTS—Continued

No. V Fuses—Continued

Fuse No.	Film No.	Stock	Fuse rating	Kw-sec.	Behavior			Remarks
					Noise	Flash	Cotton	
149	.....	J	200	18.8	Medium..	Bright.....	Scorched and blackened.....	Vented at both ends.
63	.....	J	400	24.1	...do.....	Mild.....	Scorched at indicator and blown away.....	Do.
64	.....	J	400	24.8	...do.....	Medium..	.....do.....	Do.
65	3-D	J	400	24.7	Light.....	Mild.....	.....do.....	Vented at one end. Did not indicate.
66	4-D	J	400	25.5	...do.....	...do.....	Ignited.....	Do.
160	.....	J & R	400	25.4	...do.....	None.....	Slightly scorched.....	Vented at one end.
161	.....	.....	400	27.7	...do.....	Medium..	Blackened.....	Do.
217	4-N	J	400	33.7	...do.....	None.....	.....do.....	Did not indicate.
218	.....	J & R	400	23.3	...do.....	Medium..	Blackened and blown away at one end.....	Vented at one end.
183	3-K	.....	600	68.6	Medium..	Bright.....	Scorched at one cap.....	Did not indicate.
					Economy Fuses			
107	.....	.....	30	1.5	Very loud.	Bright.....	Blown away.....	Fiber shell split and blown apart.
108	.....	.....	30	15.3	Violent....	...do.....	.....do.....	Fiber shell blown out one side.
109	.....	.....	30	4.1	Very loud.	...do.....	Ignited.....	Do.
110	.....	.....	30	15.5	...do.....	...do.....	.....do.....	Do.
111	.....	.....	30	2.9	...do.....	...do.....	.....do.....	Do.
112	.....	.....	30	38.4	...do.....	...do.....	.....do.....	Do.
113	.....	.....	30	1.6	None.....	...do.....	No effect.....	
114	.....	.....	30	1.4	...do.....	...do.....	Slightly blackened.....	
115	.....	.....	30	1.4	Violent....	...do.....	Ignited.....	Fiber shell blown out one side.
116	3-E	R	30	1.6	None.....	None.....	No effect.....	
116A	4-E	.....	30	1.6	...do.....	...do.....	.....do.....	
116B	5-E	.....	30	1.6	Medium..	...do.....	.....do.....	
116C	1-F	.....	30	1.6	None.....	...do.....	.....do.....	
143	.....	.....	30	.....	Loud.....	Bright.....	Ignited.....	Fiber shell blown out one side.
144	3-G	.....	30	2.9	...do.....	...do.....	.....do.....	
145	4-G	.....	30	2.7	Medium..	...do.....	.....do.....	
201	2-M	.....	60	1.7	None.....	None.....	No effect.....	
202	3-M	.....	60	3.1	...do.....	...do.....	.....do.....	
203	.....	.....	60	3.7	...do.....	...do.....	Blackened.....	
204	.....	.....	60	3.3	...do.....	Mild.....	No effect.....	

205	.....	.....	60	3.3	...do.....	None.....	Slightly blackened.....	
206	.....	.....	60	3.4	...do.....	...do.....	None used.....	
25	1-K	R	100	5.7	Loud.....	Bright.....	Ignited.....	
26	2-K	.....	100	5.9	...do.....	...do.....	.....do.....	
27	.....	R	100	5.7	...do.....	...do.....	.....do.....	
28	.....	R	100	5.1	Violent.....	...do.....	.....do.....	Fiber shell shattered.
29	.....	.....	100	5.3	Light.....	None.....	Blackened.....	
30	.....	R	100	5.2	Medium..	Bright.....	Ignited.....	
31	.....	.....	200	10.5	Loud.....	...do.....	.....do.....	
32	.....	.....	200	9.9	Light.....	Mild.....	Blackened.....	
33	3-A	.....	200	10.5	...do.....	...do.....	.....do.....	
34	4-A	.....	200	10.3	...do.....	...do.....	.....do.....	
35	.....	.....	200	10.3	Medium..	Medium..	Ignited.....	
36	.....	R	200	10.4	...do.....	...do.....	Blackened.....	
156	.....	R	200	11.0	...do.....	Mild.....	Slightly scorched at cap.....	
157	.....	.....	200	10.5	...do.....	Bright.....	Ignited.....	
173	.....	R	400	17.5	None.....	None.....	Blackened.....	
174	.....	.....	400	18.1	Light.....	...do.....	.....do.....	
221	1-O	R	400	15.9	...do.....	...do.....	.....do.....	
222	.....	R	400	17.7	...do.....	Medium..	Blackened and blown away at both ends.....	Vented at one end.
196	3-L	.....	600	18.8	...do.....	None.....	Blackened.....	
197	.....	.....	600	19.5	...do.....	...do.....	.....do.....	
198	4-L	.....	600	19.6	...do.....	...do.....	.....do.....	

No. VI Fuses

77	.....	.....	30	1.8	Light.....	None.....	Blackened.....	
78	.....	.....	30	2.2	None.....	...do.....	.....do.....	
79	.....	.....	30	2.1	...do.....	...do.....	.....do.....	
80	.....	.....	30	2.2	...do.....	...do.....	No effect.....	
81	.....	.....	30	2.1	...do.....	.do.....	Slightly blackened.....	
117	2-F	.....	30	2.3	...do.....	...do.....	Scorched at indicator.....	
118	.....	.....	30	2.3	Light.....	...do.....	.....do.....	
119	.....	.....	30	2.3	...do.....	...do.....	No effect.....	
126	3-F	.....	30	2.2	...do.....	...do.....	Slightly blackened.....	
127	4-F	.....	30	2.2	...do.....	...do.....	Scorched at indicator.....	
207	4-M	.....	60	4.0	Medium..	Medium..	Slightly blackened.....	Label very slightly, browned as an indication.
208	5-M	.....	60	4.3	None.....	None.....	No effect.....	
209	.....	.....	60	4.3	Light.....	...do.....	Blackened at indicator.....	
210	.....	.....	60	3.9	None.....	...do.....	No effect.....	
211	.....	.....	60	3.5	...do.....	...do.....	Scorched at indicator.....	
212	.....	.....	60	4.0	...do.....	...do.....	.....do.....	
137	.....	.....	100	8.1	...do.....	...do.....	Blown away at indicator.....	Vented at both ends.
138	1-H	.....	100	6.6	...do.....	...do.....	Scorched at indicator.....	Do.
139	2-H	.....	100	7.0	...do.....	...do.....	.....do.....	
1	1	.....	100	5.2	Light.....	Mild.....	No effect.....	
2	2	.....	100	6.2	...do.....	...do.....	.....do.....	Vented at one end. Did not indicate.
3	.....	.....	100	5.6	...do.....	...do.....	.....do.....	
4	3	.....	100	6.5	...do.....	...do.....	Scorched at indicator.....	
5	4	.....	100	7.1	...do.....	...do.....	.....do.....	

TABLE 5—Continued

Record of Fuse Shirt-Circuit Test, Boston, Mass., September, 1915—Continued

FIRST CIRCUIT CONDITION, 250 VOLTS—Continued

No. VI Fuses—Continued

Fuse No.	Film No.	Stock	Fuse rating	Kw-sec.	Behavior			Remarks
					Noise	Flash	Cotton	
6	5	.....	100	6.3	Light.....	Mild.....	Scorched at indicator.....	
146	.....	.....	200	12.9	None.....	None.....	.....do.....	
147	.....	.....	200	10.8	...do.....	...do.....	.....do.....	
7	1-A	R	200	11.3	Light.....	Mild.....	No effect.....	Label slightly raised at one point, but did not indicate. Vented at one end.
8	2-A	.....	200	11.9	...do.....	...do.....	Scorched at indicator.....	Vented at one end.
9	.....	R	200	14.3	...do.....	...do.....	.....do.....	
10	.....	R	200	12.0	...do.....	...do.....	.....do.....	Vented at one end.
11	.....	R	200	14.2	...do.....	None.....	No effect.....	Label slightly raised at one point, but did not indicate.
12	.....	R	200	13.2	...do.....	...do.....	.....do.....	Did not indicate.
59	.....	R	400	26.7	Medium..	Mild.....	Blown away at one end.....	Did not indicate. Vented at one end.
60	.....	R	400	26.5	Light.....	None.....	.....do.....	Did not indicate.
61	.....	R	400	31.4	...do.....	...do.....	Scorched at indicator and blown away.....	Vented at both ends.
62	.....	R	400	27.2	...do.....	Mild.....	.....do.....	Vented at one end.
162	.....	.....	400	25.6	...do.....	Medium..	Blackened.....	Do.
163	.....	.....	400	24.3	Medium..	Bright.....	Scorched at indicator.....	Do.
213	1-N	.....	400	23.2	Light.....	None.....	Scorched at indicator; blackened and moistened at caps.	Vented at both ends.
214	.....	.....	400	25.4	...do.....	...do.....	.....do.....	Vented at one end.
71	1-E	.....	600	29.0	Medium..	...do.....	Blackened and blown away.....	Did not indicate.
72	2-E(Blk)	.....	600	24.8	Very light	...do.....	Scorched at indicator.....	Vented at one end.
199	5-L	R	600	47.8	Light.....	Mild.....	Blown away at one end.....	Do.
200	1-M	.....	600	56.0	...do.....	Medium..	Blackened at indicator.....	Label slightly raised, but did not indicate. Vented at one end.

SECOND CIRCUIT CONDITION, 250 VOLTS

No. I Fuses

251	.....	30	1.7	None.....	Mild.....	Scorched at indicator.....	Vented at both ends.
252	R	30	1.3	...do.....	Bright....	Blackened and blown away.....	Do.
253	.....	30	1.4	...do.....	Medium..	.....do.....	Vented at one end.

254	4-Q	30	1.3	Medium	Mild	Scorched	Vented at both ends.
285		100	7.1	Light	Medium	Blackened and blown away	Do.
286	R	100	6.8	do	Mild	Blackened at indicator	Do.
287		100	7.2	do	do	do	Do.
288	2-S	100	8.4	do	Medium	Blackened	Do.
312		200	11.5	do	do	Scorched at one end	Do.
313	R	200	11.2	do	Mild	Blackened and blown away at both ends	Vented at both ends. Did not indicate.
314		200	10.8	None	Bright	Scorched at one end	Filler blown out. Vented at both ends.
323	5-T	400	23.3	Medium	Medium	Blown away	Vented at both ends.
324		400	22.0	do	do	Blown away at both ends	Did not indicate. Vented at both ends.
325		400	26.2	do	do	do	Vented at both ends.
343		600	32.1	Light	Mild	No effect	Vented at one end.
344	5-V	600	31.0	do	do	Blown away	Filler blown out. Vented at both ends.

No. II Fuses

255		30	11.3	Loud	Bright	Ignited	Indicator end cap blown off. Bent clips. Fused one clip. Cracked base.
256		30	11.9	do	do	do	Indicator end cap blown off. Bent clips.
257		30	2.0	Light	Mild	Blackened	
258	3-Q J	30	2.3	Loud	Medium	Scorched	Hole blown in center of indicator end cap.
367		30	2.0	Medium	Mild	Ignited	Do.
368		30	1.7	do	Medium	Blackened	Indicator end cap blown off. Cut-out base broken.
369	J	30	1.6	Loud	do	do	Indicator end cap blown off.
283	R	100	8.0	Light	None	do	One cap started 1/16 inch.
284	1-S R	100	7.7	do	do	Scorched at indicator	Do.
309	J & R	200	15.6	Medium	Bright	Ignited	One cap started 1/8 inch. Vented at other end.
310	J & R	200	17.4	None	None	Scorched at one cap	Vented at screws in cap.
311		200	15.6	Light	do	Scorched at indicator	One cap started 1/16 inch.
326	1-U J & R	400	49.8	do	do	Blackened	One cap started.
327	J	400	26.0	Medium	Bright	Scorched and blown away at both ends	
328		400	28.0	Light	None	Blackened	
341	4-V J	600	99.5	Medium	Medium	No effect	Vented at one end.
342	J	600	77.9	Light	do	Scorched at both ends	One cap started 1/8 inch.
A418	2-HH R	30	.7	do	Mild	Blackened at indicator end	In series with B419.
B419	2-HH	30	.4	None	None	do	In series with A418.
A420	J	30	.5	Light	Mild	do	In series with B421.
B421	J	30	.5	None	None	do	In series with A420.
A422	3-HH J & R	400	14.0	do	do	Blackened	Did not indicate. In series with B423.
B423	3-HH	400	9.7	do	do	do	Did not indicate. In series with A422.

TABLE 5—Continued

Record of Fuse Short-Circuit Test, Boston, Mass., September, 1915—Continued

SECOND CIRCUIT CONDITION, 250 VOLTS—Continued

No. III Fuses

Fuse No.	Film No.	Stock	Fuse rating	Kw-sec.	Behavior			Remarks
					Noise	Flash	Cotton	
259		R	30	1.3	Light	Bright	Scorched at indicator	
260			30	1.4	do	do	do	
261			30	1.3	do	None	No effect	
262	2-Q	R	30	1.6	do	Mild	Scorched at indicator	
275		J & R	100	7.4	do	do	Blackened and blown away	Vented at both ends.
276		J	100	8.5	do	Medium	Scorched at indicator. Blown away at both ends.	Do.
277		R	100	6.1	do	None	Blown away at one end	Vented at one end.
278	4-R	J & R	100	7.2	do	do	Scorched at indicator	Vented at both ends.
303		J	200	15.2	Medium	Bright	do	Vented at one end.
304			200	13.7	Light	None	Scorched at indicator and blown away	
305		R	200	18.3	Medium	Medium	Blown away at indicator and both ends	Vented at both ends.
317	3-T	J	400	39.5	do	Bright	Scorched at indicator and blown away at both ends.	Do.
318		R	400	50.5	do	do	do	Do.
319		J & R	400	35.0	do	do	Blown away at both ends	Do.
338	2-V	J	600	55.1	None	None	No effect	
339			600	84.9	do	do	do	Do.
A404			30	.3	do	do	Scorched at indicator	In series with B405.
B405			30	.3	do	do	do	In series with A404.
A406			30	.4	do	do	do	In series with B407.
B407			30	.4	do	do	do	In series with A406.
A408			30	.6	do	do	No effect	Did not indicate. In series with B409.
B409			30	.6	do	do	Scorched at indicator	In series with A408.
A396	4-FF	J	400	11.2	do	do	do	In series with B397.
B397	4-FF	J	400	11.3	do	do	do	In series with A396.
A398	5-FF		400	15.2	do	do	do	In series with B399.
B399	5-FF		400	18.3	do	do	No effect	In series with A398.

No. IV Fuses

239		30	1.1	Light	Mild	Scorched at indicator	
240		30	2.1	do	None	Blown away	Indicator screen and filler blown out.
241		30	2.1	Medium	do	Blackened and blown away	Vented at one end. Indicator screen and filler blown out.

242	2-R	30	2.0	Light	do	Scorched and blown away	Indicator screen and filler blown out.
364		60	3.5	None	do	No effect	
371		60	3.8	Light	Mild	do	
372	1-DD	60	3.4	do	do	do	
373	2-DD	60	3.8	do	None	Scorched at indicator	Vented at one end.
374		60	3.7	do	do	do	Do.
375		60	3.7	do	do	Slightly scorched at indicator	
376		60	3.5	do	do	do	Do.
377		60	3.5	do	do	Blackened	
378		60	3.8	do	do	No effect	Do.
379		60	3.1	do	do	Blackened	Do.
380		60	3.4	do	do	Scorched at indicator	Vented at both ends.
381		60	3.5	do	do	do	Vented at one end.
382		60	3.8	do	do	do	Do.
383		60	3.9	do	do	do	
279		100	10.0	do	do	Blackened	
280		100	10.2	None	do	No effect	
281	J	100	8.6	Light	do	Scorched	
282	5-R J	100	10.2	None	do	Hole blown in cotton at indicator	
306	J	200	20.1	do	do	Scorched at indicator	
307		200	18.8	do	do	No effect	
308	1-T J	200	20.9	Light	do	Blackened at indicator	
332	4-U	400	57.8	do	do	No effect	Cartridge moist.
333	1-X	400	30.7	None	do	do	Do.
334	2-X R	400	33.8	do	do	do	Do.
340	3-V J	600	103.0	Light	do	do	Vented at both ends. Cartridge moist.
354		600	99.2	do	do	Scorched at indicator	Do.

No. V Fuses

247		30	1.7	None	None	Scorched	Did not indicate.
248		30	1.9	do	do	Scorched through at indicator	Solder melted and blown out at one end.
249		30	1.8	Light	Mild	Scorched	
250	5-Q R	30	1.4	do	None	Scorched at indicator	
289	J	100	8.4	do	do	do	Vented at one end.
290	J & R	100	7.1	do	do	Hole blown in cotton at indicator. Blackened	
291	J & R	100	8.0	do	Bright	Blackened	Vented at one end and screw in cap.
292	3-S R	100	9.6	None	None	No effect	
350		200	14.1	do	do	Scorched at indicator	Vented at one end.
351	4-X R	200	14.1	Light	Bright	Scorched at one end	Do.
352	5-X J & R	200	14.2	do	Mild	Scorched at indicator	Do.
320	4-T J	400	22.7	do	None	Blackened	Metal blown out along blade at cap.
321	J & R	400	23.4	do	Mild	do	Vented at one end.
322	J	400	34.0	Medium	Bright	Scorched at indicator and one end	Do.
337	1-V	600	94.2	Loud	do	Ignited	Filler blown out at one end. Did not indicate.

TABLE 5—Continued

Record of Fuse Short-Circuit Test, Boston, Mass., September, 1915—Continued

SECOND CIRCUIT CONDITION, 250 VOLTS—Continued

Economy Fuses

Fuse No.	Film No.	Stock	Fuse rating	Kw-sec.	Behavior			Remarks
					Noise	Flash	Cotton	
263			30	1.1	None	None	No effect	
264			30	1.2	do	do	Blackened	
265			30	1.0	Light	do	do	
266	1-Q		30	1.0	do	do	No effect	
267			30	1.1	None	do	do	
268			30	1.1	do	do	do	
269			30	1.0	do	do	do	
270			30	1.0	do	do	do	
A' 116			30	.7	do	do	Blackened	Refilled. No new parts.
A 145	3-AA		30	.8	do	do	do	Do.
A 117			30	.8	do	do	do	Do.
361	4-AA		30	.9	do	do	do	Do.
362	5-AA		30	1.1	do	do	do	Do.
363			30	1.0	do	do	do	Do.
A 205	1-BB		60	3.0	do	do	Slightly blackened	Do.
A 202	2-BB		60	3.0	do	do	do	Do.
A 201			60	3.0	do	do	do	Do.
A 203			60	3.0	do	do	do	Do.
A 204			60	3.0	do	do	do	Do.
A 206			60	3.0	do	do	do	Do.
365			60	3.0	do	do	No effect	
366			60	2.9	do	Bright	Ignited	
294			100	11.0	Light	None	Blackened	
295			100	11.0	do	Mild	Scorched at caps	
296			100	10.8	Medium	do	Ignited	
297			100	10.7	do	do	do	
298			100	10.9	do	do	do	
299			100	11.0	do	do	Scorched at one end	
300	5-S		100	5.3	Light	do	do	
293			100	11.0	do	None	Blackened	
A 298	3-BB		100	4.8	do	Mild	Ignited	Refilled. No new parts.
A 295			100	4.0	Loud	Medium	do	Do.
A 300	4-BB		100	4.8	Light	Mild	Blackened	New outer brass and leather washers.
370	5-BB		100	5.3	do	do	Ignited	
353	1-Y		200	8.3	do	do	Scorched at both ends	

355	2-Y		200	12.4	Violent	Bright	Ignited	One cap blown off.
356	3-Y		200	8.2	Light	Mild	Blackened	
357	4-Y		200	8.2	do	None	do	
358	5-Y		200	8.2	do	Bright	Ignited	
359			200	8.0	do	None	Blackened	
A 156	1-CC		200	10.2	do	Mild	Ignited	Refilled. No new parts.
A 157			200	9.6	Loud	Bright	do	Do.
A 356	2-CC		200	9.3	Medium	do	do	New outer brass and leather washers.
A 358			200	8.9	Light	Mild	Scorched at one end	Do.
B 157			200	8.2	do	do	Slightly blackened	Do.
C 157	2-II		200	7.6	do	do	Blackened	Do.
D 157	3-II		200	7.1	Violent	Bright	Ignited	One cap blown off.
329	2-U	R	400	15.0	Light	Mild	Blackened	
330	3-U		400	15.0	do	do	do	
331			400	15.0	do	None	Scorched at one end	
A 173			400	13.4	Medium	Bright	Ignited	Refilled. No new parts.
A 174	1-Z		400	13.6	do	do	do	Do.
A 329	3-CC		400	12.7	Light	Mild	Blackened	New outer brass and leather washers.
A 330	4-CC		400	12.8	None	None	Slightly blackened	Do.
345	1-W		600		do	do	No effect	Found open circuited when tested.
346	2-W		600	17.1	Light	do	do	
347	3-W		600	15.0	do	do	do	
348	4-W		600	15.5	do	do	do	
349	5-W		600	26.3	None	do	Blackened	
A 196	2-Z		600	13.7	Light	do	do	New outer brass and old leather washers.
A 197	3-Z		600	15.5	do	Mild	do	Do.
A198			600	18.0	do	None	do	Refilled. No new parts.
A346	5-CC		600	16.4	do	do	Slightly blackened	Do.
[a] 360	4-Z		600	19.6	do	do	Blackened	
B415	4-GG		30	.1	None	do	Slightly blackened	In series with A414.
B417	5-GG		30	.3	do	do	do	In series with A416.
A424	4-HH		400	6.7	Light	do	Blackened	In series with B425.
B425	4-HH		400	4.6	do	do	No effect	In series with A424.
A426	5-HH		400	5.2	None	Mild	Blackened	In series with B427.
B427	5-HH		400	6.7	do	do	do	In series with A426.
A428	1-II	R	400	4.4	do	None	do	In series with B429.
B429	1-II	R	400	6.9	do	Mild	do	No load in parallel on battery. In series with A428.

No. VI Fuses

243			30	1.8	Medium	None	Scorched at indicator
244			30	1.9	Light	do	do
245			30	2.0	do	do	do
246	1-R		30	.9	do	do	do
271			100	6.5	do	do	do
272			100	6.5	do	do	do
273			100	6.2	do	do	do
274	3-R		100	5.6	do	do	do

[a] This fuse supplied by Guy Cunningham and tested on request.

TABLE 5—Continued

Record of Fuse Short-Circuit Test, Boston, Mass., September, 1915—Continued

SECOND CIRCUIT CONDITION, 250 VOLTS—Continued

No. VI Fuses—Continued

Fuse No.	Film No.	Stock	Fuse rating	Kw-sec.	Behavior			Remarks
					Noise	Flash	Cotton	
301	.....	.....	200	10.1	Light	None	Scorched at indicator	
302	.....	.....	200	7.8	...do	...do	...do	
315	2-T	R	400	38.5	None	Mild	Scorched at one end and indicator	Vented at both ends.
316	.....	R	400	17.3	Light	None	No effect	Vented at one end. Label off, but indicator wire not fused.
335	5-U	R	600	65.1	Medium	Very bright	Scorched at one end	Vented at one end.
336	3-X	R	600	41.2	None	None	No effect	Did not indicate.
B411	3-GG	R	30	.4	...do	...do	Scorched at indicator	In series with A410.
A410	3-GG	.....	30	.5	...do	...do	...do	In series with B411.
A412	1-HH	.....	30	.4	...do	...do	Blackened	In series with B413.
B413	1-HH	.....	30	.3	...do	...do	...do	In series with A412.
A400	1-GG	J	400	6.6	...do	...do	Scorched at indicator	In series with B401.
B401	1-GG	J	400	4.8	.. do	...do	...do	In series with A400.
A402	2-GG	J	400	5.5	...do	...do	...do	In series with B403.
B403	2-GG	J	400	5.8	...do	...do	...do	In series with A402.
					No. III Fuses [a]			
384	3-DD	.....	30	1.1	Light	Medium	Slightly blackened	
387	1-EE	.....	30	1.7	...do	None	Slightly scorched	
388	2-EE	.....	60	4.4	...do	Medium	...do	Vented at both ends.
389	.....	.....	60	3.1	...do	None	...do	
394	2-FF	.....	100	5.3	Medium	...do	Slightly blackened	Filler blown out at both ends.
395	3-FF	.....	100	5.3	Light	Mild	...do	Vented at one end.
					Economy Fuses [a]			
385	4-DD	.....	30	12.6	Loud	Bright	Ignited	Fiber shell blown out one side. Fused clips.
386	5-DD	.....	30	5.5	...do	...do	...do	Fiber shell blown out one side. Fused one clip.
390	3-EE	.....	60	55.4	Violent	...do	...do	Fiber shell shattered and blown out of clips.
391	4-EE	.....	60	3.0	...do	...do	...do	One cap blown off. Bent clips. Fuse link replaced with new one by B. S. before test.

392	5-EE	.....	100	4.8	...do.....	...do.....	.....do.....	One cap blown off. New leather washers. Bent clips. Fuse link replaced with new one by B. S. before test.
393	1-FF	.....	100	36.6	...do.....	...do.....	...do.....	Fiber shell blown out one side.
A414	4-GG	.....	30	.4	None.....	None.....	Slightly blackened.....	In series with B415.
A416	5-GG	.....	30	.4	...do.....	...do.....	.....do.....	In series with B417.

THIRD CIRCUIT CONDITION, 250 VOLTS

No. I Fuses

442	1-KK	.....	30	0.9	Medium..	Mild.....	Scorched at indicator.....	Vented at both ends.
443	2-KK	.....	30	.9	Light.....	...do.....	.....do.....	Do.
460	.....	R	100	8.9	...do.....	Medium..	Blackened.....	Vented at both ends. Did not indicate.
461	1-MM	.....	100	5.2	None.....	None.....	.....do.....	Vented at both ends.

No. II Fuses

438	4-JJ	.....	30	1.1	Light.....	Mild.....	Blackened.....	
439	5-JJ	J	30	1.9	...do.....	Medium..	.....do.....	One cap started.
440	.....	J	30	1.4	Loud.....	Bright.....	.....do.....	Hole blown in center of indicator end cap.
441	.....	J	30	1.6	...do.....	...do.....	.....do.....	Do.

No. III Fuses

432	1-JJ	.....	30	1.1	None.....	Mild.....	Scorched at indicator.....	
433	.....	.....	30	1.1	...do.....	None.....	.....do.....	
434	.....	.....	30	1.2	Light ...	Mild.....	.....do.....	
456	1-LL	.....	100	8.0	None.....	None.....	Blackened.....	Vented at both ends.
457	.....	.....	100	10.1	...do.....	Medium..	Scorched and blown away at both ends.....	

No. IV Fuses

435	2-JJ	.....	30	1.3	Light.....	Mild.....	Blown away.....	Indicator screen and filler blown out.
436	3-JJ	.....	30	1.2	...do.....	None.....	Scorched at indicator.....	
437	.....	.....	30	1.3	...do.....	...do.....	Scorched at indicator and blown away.....	Vented at one end.
458	.....	.....	100	11.0	None.....	...do.....	No effect.....	
459	5-LL	.....	100	10.0	...do.....	...do.....	Blackened.....	

[a] The fuses grouped under this heading were supplied by the D. & W. Fuse Co., after 50-hour run at rated current: admitted as evidence suject to verification by the Bureau of Standards.

TABLE 5—Continued

Record of Fuse Short-Circuit Test, Boston, Mass., September, 1915—Continued

THIRD CIRCUIT CONDITION, 250 VOLTS—Continued

Fuse No.	Film No.	Stock	Fuse rating	Kw-sec.	Behavior			Remarks
					Noise	Flash	Cotton	
No. V Fuses								
444	3-KK	.....	30	1.0	None	None	Scorched at indicator	
445	.....	R	30	1.1	...do	...do	Blackened at indicator	
446	.....	.....	30	1.1	...do	...do	Scorched	
462	2-MM	.....	100	4.3	...do	...do	Blown away at indicator	
Economy Fuses								
447	.....	.....	30	0.8	None	None	Slightly blackened	
A144	4-KK	.....	30	.8	...do	...do	Slightly scorched at one end	
A415	5-KK	.....	30	.7	Light	...do	No effect	
A417	.....	.....	30	.9	None	Mild	Blackened	
448	.....	.....	60	3.5	...do	None	No effect	
449	.....	.....	60	3.5	...do	Mild	Blackened	
450	.....	.....	60	3.5	...do	None	...do	
451	3-LL	.....	60	3.4	...do	...do	No effect	
452	.....	.....	60	3.4	...do	...do	...do	
463	4-LL	.....	60	3.5	...do	...do	Slightly blackened	
464	.....	.....	200	8.3	...do	Mild	Blackened	
465	.....	.....	200	7.5	...do	None	...do	
466	.....	.....	200	.....	...do	...do	No effect	
467	.....	.....	400	6.4	...do	Mild	...do	
468	.....	.....	400	6.3	...do	...do	...do	
No. VI Fuses								
430	4-II	.....	30	1.2	None	None	Scorched at indicator	
431	5-II	.....	30	1.2	...do	...do	...do	
453	.....	.....	100	6.5	...do	...do	No effect	Did not indicate.
454	.....	J	100	6.5	...do	...do	Blackened	
455	2-LL	J	100	7.0	...do	...do	Scorched at indicator	

The following summaries of 250-volt fuse short-circuit test failures show the number of each type of fuse failure which occurred in each size tested. Six main divisions of failure are recognized:

A = Injury to cartridge fiber shell.
B = Blowing off of cap.
C = Injury to cut-out.
D = Ignition of cotton.
E = Holding or sustaining the arc.
F = Remaking of the circuit.

The fuses recorded failed under one of the two circuit conditions:

First. A circuit of approximately the values of resistance = 0.025 ohm and reactance (at 60 cycles) = 0.07 ohm.

Second. A circuit of approximately the values of resistance = 0.025 ohm and reactance (at 60 cycles) = 0.04 ohm.

In some instances fuses developed more than one kind of failure, making the total number of fuses failed less than the number of failures. The per cent of failures is the ratio of total failures to total fuses tested.

The spaces designated by "0" indicate that fuses were tested but no failures resulted under that division. For other terms, see explanation accompanying the short-circuit test data.

TABLE 6

Summary of Fuse Short-Circuit Tests, Boston, Mass., September, 1915

(*a*) FERRULE TYPE FUSES

Make of fuse	Circuit condition	Failure						Number tested	Per cent failed	Per cent of failures
		A	B	C	D	E	F			
No. I	First	0	0	0	0	0	0	10	0	0
	Second	0	0	0	0	0	0	4	0	0
No. II	First	0	12	7	7	0	0	15	100	173
	Second	0	4	3	3	0	0	7	57	143
No. III	First	0	0	0	1	0	0	7	14	14
	Second	0	0	0	0	0	0	4	0	0
No. IV	First	0	0	0	1	0	0	8	12	12
	Second	0	0	0	0	0	0	18	0	0
No. V	First	0	0	0	3	0	0	13	23	23
	Second	0	0	0	0	0	0	4	0	0
Economy	First	8	0	0	8	0	0	22	45	73
	Second	0	0	0	1	0	0	22	5	5
No. VI	First	0	0	0	0	0	0	16	0	0
	Second	0	0	0	0	0	0	4	0	0

TABLE 6—Continued

Summary of Fuse Short-Circuit Tests, Boston, Mass., September, 1915—Continued

(*b*) KNIFE-BLADE TYPE FUSES

Make of fuse	Circuit condition	Failure						Number tested	Per cent failed	Per cent of failures
		A	B	C	D	E	F			
No. I	First	0	0	0	0	0	0	27	0	0
	Second	0	0	0	0	0	0	12	0	0
No. II	First	0	0	0	0	0	0	10	0	0
	Second	0	0	0	1	0	0	10	10	10
No. III	First	0	0	0	0	0	0	23	0	0
	Second	0	0	0	0	0	0	12	0	0
No. IV	First	0	0	0	0	0	0	15	0	0
	Second	0	0	0	0	0	0	12	0	0
No. V	First	0	0	0	1	0	0	26	4	4
	Second	0	0	0	1	0	0	17	9	9
Economy	First	1	0	0	8	0	0	21	38	43
	Second	0	2	0	14	0	0	42	33	38
No. VI	First	0	0	0	0	0	0	29	0	0
	Second	0	0	0	0	0	0	10	0	0

TESTS ON 600-VOLT FUSES IN CHICAGO, ILL.

The third series of fuse tests was made at one of the plants of the Commonwealth Edison Co., of Chicago. These tests were for the most part made on 600-volt fuses with a single fuse only in the circuit.

1. *Circuit Conditions During Tests.*—Two separate circuit conditions were used, in the first of which the resistance in the circuit varied considerably because of the high initial resistance of the battery, which gradually fell off as the test proceeded. This battery had stood for a considerable time before being used, and evidently had high resistance due to sulphation. In this series the limiting current varied from about 10 000 amperes in the beginning to approximately 15 000 amperes at the end, the circuit inductance being 0.210 millihenry. As soon as this rise of current was observed from the oscillograph records the resistance of the circuit was readjusted to give a limiting current of 10 000 amperes, and it remained quite constant throughout the second series of tests. This change in the resistance also changed the inductance of the circuit to 0.277 millihenry.

2. *Rating of Fuses.*—Representative samples of all sizes and makes of inclosed fuses were selected as in the rating test at Boston and rated under standard conditions at the laboratory of the Commonwealth Edison Co. These rating tests were participated in by representatives of the various fuse manufacturers.

The failures on rating test are given in Table 7, which is identical in form and column heading with that giving the Boston test data.

Thermocouples used on these 600-volt fuses occupied a relatively smaller percentage of the surface of the fiber shells, but were present in approximately 64 per cent of fuse failures. Two makes, the VI and Economy fuses, did not have a single failure on the rating tests. In one instance two 60-ampere make V fuses which failed were found to be stock purchased from jobbers. On the fiber shells were stamped the number 55, which had been made almost undecipherable by cutting the surface of the fiber away at such places. Their labels read 60-ampere rating. Two fuses of the same make, of 200-ampere rating, heated excessively under rating test, then smoked, charred, and finally cracked the fiber shells apart at the centers. Molten fuse elements dropped out through these cracks upon the cut-out base. In general, a considerable amount of time elapsed before failures.

TABLE 7

Failure of 600-Volt Cartridge Fuses on Rating Test at Testing Laboratories of the Commonwealth Edison Co., Chicago, Ill.

Date	Current	Make of fuse	Minutes before blowing	Thermocouple on fuse	Voltage of circuit	Average temperature of room
1915	Amp.					° F
Sept. 27	33	I	110	Yes	110.0	82.0
28	220	V	65	No	2.18	77.0
28	220	V	115	Yes	2.18	77.0
28	220	V	170	Yes	2.18	77.0
28	220	V	195	No	2.18	77.0
28	66	V	50	Yes	110.0	77.0
28	66	V	50	Yes	110.0	77.0
28	66	II	30	No	110.0	80.5
28	66	II	45	No	110.0	81.0
28	66	II	70	Yes	110.0	81.0
28	220	I	85	Yes	2.18	81.0
28	66	V	15	Yes	110.0	84.0
28	66	V	25	Yes	110.0	84.0
29	33	IV	15	Yes	110.0	79.5
29	440	I	90	Yes	2.18	86.0
29	440	I	127	No	2.18	86.0
30	220	IV	133	Yes	2.18	80.0
30	110	IV	135	No	110.0	78.5
30	33	III	23	Yes	110.0	78.5
30	220	IV	116	Yes	2.18	81.0
30	33	III	55	No	110.0	82.0
30	110	I	95	No	110.0	84.0

In the summary sheet, Table 8, the precentage of failures of the approved fuses as a group is shown to be but slightly greater than experienced in the 250-volt rating tests. In both series of tests contact troubles at ferrules and knife blades, because of the poor alignment of the clips on the new cut-outs used, tended to increase the percentage of fuse failures. With the exception of a single make of approved fuse the performance on rating was considered sufficiently good to justify proceeding with the short-circuit tests.

TABLE 8

Summary of 600-Volt Fuse Rating Tests at Chicago, Ill.

Make of fuse	Ampere rating					Performance	
	30	60	100	200	400	Total failures	Per cent failures
Economy	5	4	3	4	2	0	0
I	6	7	5	5	3	5	19.2
V	8	10	5	8	2	8	24.2
II	5	7	3	3	2	3	15
IV	6	5	5	4	2	4	18.2
III	7	4	3	0	2	2	12.5
VI	5	4	3	3	2	0	0

Total of all approved fuses failed, 22; total of all approved fuses rated, 134; per cent failures of all approved fuses, 16.4.

3. *Results of Short-Circuit Tests on 600-Volt Fuses.*—The results of these tests are shown in Table 9, and are summarized in Table 10, the arrangement of the tables being the same as that described above under the 250-volt tests, so that the summarizing Table 10 needs no detailed interpretation.

TABLE 9

Record of Fuse Short-Circuit Test, Chicago, Ill., September–October, 1915

FIRST CIRCUIT CONDITION, 600 VOLTS

No. I Fuses

Fuse No.	Film No.	Stock [a]	Fuse rating	Kw-sec.	Behavior			Remarks
					Noise	Flash	Cotton	
2	.....	.....	30	11.8	None	Bright	Blown away	
3	.....	R	30	10.4	Medium	do	do	Filler blown out at one end.
4	.....	.....	30	11.8	Loud	do	do	Filler blown out at both ends.
5	.....	.....	30	11.1	do	do	do	Filler blown out at one end.
6	.....	.....	30	14.4	do	do	do	One cap blown off. Filler blown out at other end. Bent clips.
7	.....	.....	30	11.8	do	do	do	Solder melted and blown out at both ends.
8	.....	R	30	11.1	do	Medium	do	Do.
9	.....	.....	30	3.0	None	do	No effect	One cap blown off. Filler blown out at other end. Bent clips.
34	B-6	R	30	10.2	Medium	Bright	do	
35	.....	R	60	12.8	Very loud	do	Blown away	Both caps blown off. Bent clips.
36	.....	.....	60	12.8	do	do	do	Do.
37	.....	.....	60	12.8	Loud	do	do	Do.
38	.....	R	60	12.3	do	do	do	Do.
39	.....	.....	60	12.8	do	do	do	One cap blown off. Bent clips.
40	.....	R	60	11.2	do	do	do	One cap blown off. No load in parallel on battery.
65	B-11	R	60	11.8	Violent	do	do	Both caps blown off. Bent clips.
105	.....	.....	100	19.3	Medium	None	do	Vented at both ends.
106	.....	.....	100	20.3	do	do	do	Do.
107	.....	.....	100	21.4	do	do	do	Do.
85	.....	.....	200	32.8	do	do	do	Filler blown out at one end.
86	.....	.....	200	32.3	do	do	do	Vented at both ends.
87	.....	R	200	32.6	None	Medium	Blackened	Do.
88	.....	R	200	43.0	Loud	Bright	No effect	Vented at one end.

[a] R=rated; J=taken from jobber's stock. Where no symbol is given the fuse was supplied by manufacturer.

TABLE 9—Continued

Record of Fuse Short-Circuit Test, Chicago, Ill., September–October, 1915—Continued

FIRST CIRCUIT CONDITION, 600 VOLTS—Continued

Fuse No.	Film No.	Stock	Fuse rating	Kw-sec.	Behavior			Remarks
					Noise	Flash	Cotton	
No. II Fuses								
16	.....	R	30	5.4	None	Mild	No effect	
17	.....	R	30	10.4	...do	...do	...do	
19	.....	R	30	5.4	...do	...do	...do	
21	.....	R	30	4.3	...do	None	...do	Vented at one end.
48	.....	.....	60	11.2	Very loud	Medium	Scorched at indicator	Indicator end cap loosened. Other cap blown off.
49	.....	.....	60	11.2	Loud	...do	Scorched	Indicator end cap loosened. Other cap blown off. Clips Broken off.
50	.....	R	60	12.3	Hiss	...do	No effect	
51	.....	R	60	11.2	Loud	Bright	Blown away	Cap opposite indicator end blown off. Indicator end cap driven on shell.
52	.....	.....	60	10.9	Hiss	None	No effect	
70	B–16	.....	100	.....	Loud	Mild	Blackened	Vented at one end.
71	B–18	.....	100	.....	...do	...do	No effect	
72	.....	.....	100	.....	...do	...do	Blown away	One cap blown off. Bent clips.
89	.....	R	200	32.1	Medium	...do	...do	Filler blown out at one end.
90	.....	R	200	32.3	...do	None	...do	Do.
91	B–24	.....	200	21.4	...do	...do	...do	
No. III Fuses								
56	.....	.....	30	3.7	None	None	No effect	
57	.....	.....	30	3.7	...do	...do	...do	
58	.....	.....	30	4.3	...do	Mild	Blackened	Filler blown out at one end.
59	.....	.....	30	3.7	...do	None	Blackened and blown away	
60	.....	.....	30	.....	Medium	...do	No effect	
61	B–7	.....	30	.....	None	Mild	Blown away	
62	B–8	.....	60	.....	...do	...do	...do	Filler blown out at one end. Solder melted at one end.
63	B–9	.....	60	15.0	Light	Bright	...do	Filler blown out at one end. Vented at other end.
64	B–10	.....	60	15.5	...do	...do	...do	Filler blown out at one end. Fuse element blown out.
92	.....	.....	100	21.4	Medium	None	...do	Filler blown out at both ends.
93	.....	.....	100	17.1	...do	Mild	...do	Do.
94	.....	.....	100	17.1	...do	...do	...do	Do.
95	.....	.....	100	22.5	Loud	Bright	...do	Do.
96	.....	.....	100	20.3	Medium	None	...do	Do.
81	B–22	.....	400	.....	Light	...do	No effect	

No. IV Fuses

118	.....	.....	30	4.3	Light	None	No effect	
119	.....	.....	30	4.3	...do	...do	...do	
120	.....	.....	30	3.9	...do	...do	...do	
114	.....	.....	60	10.7	...do	...do	...do	Filler blown out at both ends.
115	.....	.....	60	10.7	...do	...do	...do	Do.
116	.....	.....	60	11.8	...do	...do	...do	Do.
117	.....	.....	60	9.6	...do	...do	...do	Do.
108	.....	.....	100	21.4	Medium	...do	Blown away	Cartridge moist.
109	.....	.....	100	21.4	...do	...do	...do	Do.
110	.....	.....	100	20.3	...do	...do	...do	Do.

No. V Fuses

10	.....	.....	30	3.0	None	Mild	No effect	
11	.....	.....	30	4.4	...do	...do	...do	
12	.....	R	30	4.4	...do	...do	...do	
13	.....	R	30	3.7	...do	...do	...do	No load in parallel on battery.
14	.....	R	30	4.4	...do	...do	...do	
15	.....	.....	30	4.3	...do	...do	...do	
68	B–14	R	30	2.1	...do	None	...do	
69	B–15	R	30	4.3	...do	...do	...do	
41	.....	R	60	15.0	Light	Bright	Ignited	
42	.....	R	60	12.8	...do	...do	No effect	Vented at one end.
43	.....	R	60	14.7	Very loud	...do	Blown away	One cap blown off. One clip broken off. Bent clips.
111	.....	.....	100	17.1	Medium	Medium	Ignited	Filler blown out at one end. Metal blown out along blade. Did not indicate.
112	.....	.....	100	17.1	...do	None	Blown away	Vented at both ends. Bent clip.
113	.....	.....	100	21.4	...do	Bright	Blackened and blown away	Vented at both ends.
82	B–23	.....	200	.....	...do	Medium	Ignited	Filler blown out at both ends.
83	.....	.....	200	32.1	...do	Bright	Blackened	Do.
84	.....	.....	200	42.8	...do	...do	Blown away	Do.

Economy Fuses

22	.....	.....	30	4.3	None	None	No effect	
23	.....	R	30	4.3	...do	...do	...do	
24	.....	.....	30	3.2	...do	...do	...do	
25	.....	.....	30	3.2	...do	...do	...do	
26	.....	.....	30	3.7	...do	...do	...do	
27	.....	.....	30	3.7	...do	...do	...do	
28	.....	R	30	3.7	...do	...do	...do	
29	.....	.....	30	3.7	...do	...do	...do	
30	.....	.....	30	3.2	...do	...do	...do	
31	B–3	.....	30	4.0	...do	...do	...do	

TABLE 9—Continued

Record of Fuse Short-Circuit Test, Chicago, Ill., September–October, 1915—Continued

FIRST CIRCUIT CONDITION, 600 VOLTS—Continued

Economy Fuses—Continued

Fuse No.	Film No.	Stock	Fuse rating	Kw-sec.	Behavior			Remarks
					Noise	Flash	Cotton	
32	B–4	.....	30	3.6	Medium	None	No effect	
33	B–5	R	30	3.7	None	do	do	
53	.....	.....	60	6.4	Violent	Bright	Blown away	One screw plug blown out.
54	.....	.....	60	6.4	do	do	do	Do.
55	.....	.....	60	6.4	do	do	Ignited and blown away	Both screw plugs blown out. Bent clips.
102	.....	.....	100	16.1	do	do	Blown away	Both screw plugs blown out. Bent clip.
103	.....	.....	100	13.9	do	do	do	One screw plug blown out. Bent clips.
104	.....	.....	100	22.5	do	do	do	Both screw plugs blown out. Bent clips.
					No. VI Fuses			
66	B–12	R	30	.....	None	None	No effect	
67	B–13	R	30	.....	do	do	do	
44	.....	R	60	13.1	Hiss	do	do	Did not indicate.
45	.....	R	60	12.8	do	do	do	
46	.....	R	60	12.8	do	do	Scorched at one end	
47	.....	R	60	12.8	do	Medium	Scorched at indicator	
97	.....	.....	100	16.1	Medium	None	No effect	Cartridge moist at caps. Did not indicate.
98	.....	.....	100	15.0	do	do	do	Cartridge moist at caps.
99	.....	.....	100	13.9	do	do	do	Do.
100	.....	.....	100	15.0	do	do	do	Do.
101	.....	.....	100	13.9	None	do	Scorched at indicator	Do.
74	.....	.....	200	.....	do	do	Blown away	Filler blown out at both ends.
75	.....	.....	200	.....	Medium	do	do	Do.
76	.....	.....	200	.....	do	do	Moist at both ends; blown away	
77	.....	.....	200	.....	do	Bright	No effect	Vented at one end.
78	B–19	.....	200	.....	do	None	do	Cartridge moist at cap.
79	B–20	.....	200	.....	Light	do	Blown away	Do.
80	B–21	.....	400	.....	Loud	Mild.	do	Filler blown out at both ends.

SECOND CIRCUIT CONDITION, 600 VOLTS

No. I Fuses

218	B-44	R	30	8.6	Loud	Bright	Scorched	Vented at both ends. Solder melted and blown out at both ends.
219		J	30	7.5	do	Medium	Blackened	Vented at one end.
220		R	30	8.6	do	do	Blown away	Vented at both ends. Solder melted and blown out at one end.
221			30	8.6	Light	do	Ignited	Vented at one end.
222			30	8.6	Loud	Bright	Scorched and blown away	Vented at both ends. Solder melted and blown out at both ends.
223			30	8.6	do	do	do	Vented at both ends. Solder melted and blown out at one end.
224			60	11.8	Hiss	do	No effect	Vented at both ends.
225	B-45		60	11.8	do	do	do	Do.
226			60	10.7	do	do	Blackened	Do.
227			60	10.7	do	None	do	Do.
228			60	11.8	Medium	Bright	do	Do.
229			60	10.7	None	None	No effect	
230		R	100	16.0	Light	Medium	Scorched	Do.
231	B-46	R	100	12.8	do	do	Blown away	Vented at one end.
232			100	15.0	do	do	Blackened and blown away	Do.
233			100	16.0	do	do	do	Do.
234			100	15.0	do	do	do	Do.
235		R	100	16.0	do	Mild	do	Vented at both ends.
351			100	16.0	None	do	Scorched at indicator	Do.
236	B-47	R	200	53.5	Loud	do	No effect	Do.
237			200	28.9	Hiss	None	Blown away	Cartridge moist.
238			200	23.6	do	do	do	Cartridge moist. Vented at one end.
239		R	200	53.5	Loud hiss	do	do	Vented at both ends.
240			200	46.0	do	Medium	do	Vented at one end.
304			400	53.5	Medium	do	do	Filler blown out at both ends. Cartridge moist.
305	B-58	R	400	73.9	Loud	do	do	Do.

No. II Fuses

195			30	3.2	None	None	Scorched at indicator	Vented at one end.
196	B-40		30	4.3	do	Mild	Scorched at ends	Do.
197			30	3.2	do	None	No effect	Do.
198			30	4.3	Light	do	do	Do.
199			30	3.2	None	do	do	Do.
200			30	3.2	do	do	do	Do.
393		J	30	4.6	Loud	Bright	Blackened	Cartridge blown out of clips. Cap at indicator end blown off.
394		J	30	4.4	None	Mild	do	Vented at one end.
395		J	30	3.9	do	None	No effect	Do.
201			60	8.6	Light	Mild	do	Cartridge moist.

TABLE 9—Continued

Record of Fuse Short-Circuit Test, Chicago, Ill., September–October, 1915—Continued

SECOND CIRCUIT CONDITION, 600 VOLTS—Continued

No. II Fuses—Continued

Fuse No.	Film No.	Stock	Fuse rating	Kw-sec.	Behavior			Remarks
					Noise	Flash	Cotton	
202	B–41	.....	60	9.6	None	None	No effect	Cap screw blown out.
203	.....	.....	60	9.6	Hiss	Mild	...do	Cap screws loosened.
204	.....	.....	60	9.6	None	...do	...do	
205	.....	.....	60	9.6	Violent	Bright	Blown away	One cap blown off. Bent clips.
206	.....	.....	60	9.6	Hiss	None	No effect	
369	.....	R	60	10.5	Light	...do	...do	Vented at one end.
370	.....	.....	60	10.6	Hiss	...do	...do	
371	.....	.....	60	10.2	...do	...do	...do	
372	.....	J	60	11.8	Loud	...do	...do	Indicator end cap blown off. Vented at other end. Bent clip.
373	.....	J	60	11.8	Medium	Bright	...do	Vented at one end.
374	.....	J	60	11.1	Loud	Medium	Blown away	Cap opposite indicator end blown off. Indicator end cap crushed on shell by impact against cage.
207	B–42	R	100	16.0	None	Mild	No effect	Cartridge moist. Vented at one end.
208	.....	.....	100	16.0	Light	None	Blown away	Cartridge moist. Did not indicate.
209	.....	R	100	12.8	...do	...do	Blackened	Cartridge moist. Vented at one end.
210	.....	R	100	7.5	Loud	...do	Blackened and blown away	Vented at one end.
211	.....	.....	100	11.8	Light	...do	Blown away	Cartridge moist.
212	.....	.....	100	13.9	...do	...do	Blackened	Do.
336	.....	J	100	9.6	...do	...do	Blackened and blown away	
337	.....	J	100	15.6	...do	Bright	Ignited	
338	.....	J	100	17.1	...do	None	Blackened	
213	.....	.....	200	30.0	...do	...do	No effect	Cartridge moist.
214	.....	.....	200	32.1	...do	...do	...do	Do.
215	B–43	.....	200	23.5	None	...do	Blown away	Do.
216	.....	R	200	53.5	Light hiss	Mild	No effect	Did not indicate. Vented at one end.
217	.....	.....	200	33.2	Hiss	None	...do	Cartridge moist.
329	.....	J	200	23.6	Loud	...do	Blackened at indicator	Vented at one end.
330	.....	J	200	31.0	...do	Bright	Ignited and blown away	
311	.....	R	400	117.0	Medium	Medium	Ignited	Remade circuit several times. Four minor explosions, bright flame following each one. Cap fused open at one corner. Cap split open.
312	.....	.....	400	63.1	...do	...do	No effect	Remade circuit once. Cartridge moist. Expanded caps. One minor explosion.
313	B–60	R	400	97.5	...do	Bright	Scorched	Remade circuit twice. Cartridge moist. Expanded caps. Two minor explosions, bright flame following each one. Circuit breaker then opened to break arc.

314	.....	.....	400	78.1	Light hiss.	None.....	No effect.....	Cartridge moist.
315	.....	.....	400	84.5	Long hiss..	...do.....	.....do.....	Expanded caps. Cartridge moist.

No. III Fuses

123	.....	.....	30	4.3	None.....	None.....	No effect.....	
124	.....	.....	30	4.3	...do.....	Medium..	.....do.....	
125	.....	.....	30	3.2	...do.....	None.....	.....do.....	
126	.....	.....	30	4.3	...do.....	...do.....	.....do.....	
127	B–27	.....	30	4.3	...do.....	...do.....	.....do.....	
128	.....	.....	30	3.2	...do.....	...do.....	.....do.....	
381	.....	R	30	3.6	...do.....	...do.....	.....do.....	
382	.....	J & R	30	3.5	Light.....	Mild.....	Blackened at indicator.....	
383	.....	R	30	3.6	...do.....	None.....	.....do.....	
129	B–28	R	60	15.0	None.....	Bright.....	Scorched at indicator.....	
130	.....	R	60	15.0	...do.....	...do.....	Blown away at indicator.....	
131	B–29	.....	60	15.0	...do.....	None.....	.....do.....	Vented at one end.
132	.....	.....	60	12.8	Light.....	...do.....	No effect.....	Do.
133	.....	R	60	12.8	...do.....	Medium..	Blown away.....	
134	.....	.....	60	12.8	...do.....	...do.....	.....do.....	
358	.....	J	60	10.7	...do.....	None.....	Blackened.....	Vented at both ends.
359	.....	J	60	10.4	...do.....	...do.....	Blown away.....	Do.
360	.....	J	60	10.2	...do.....	Bright.....	.....do.....	Do.
361	.....	J	60	10.4	...do.....	Medium..	Blackened.....	Do.
362	.....	R	60	12.8	...do.....	...do.....	Blackened and blown away.....	
363	.....	.....	60	12.0	None.....	...do.....	.....do.....	
135	B–30	.....	100	21.4	Medium..	...do.....	Blown away.....	Do.
136	.....	.....	100	22.5	...do.....	...do.....	.....do.....	Do.
137	.....	.....	100	21.4	...do.....	...do.....	.....do.....	Do.
138	.....	.....	100	25.7	...do.....	...do.....	.....do.....	Do.
139	.....	.....	100	18.2	...do.....	...do.....	.....do.....	Vented at one end.
140	.....	.....	100	21.4	...do.....	...do.....	.....do.....	Vented at both ends.
345	.....	J	100	20.9	Light.....	...do.....	Blackened.....	Vented at one end.
346	.....	J	100	35.6	...do.....	...do.....	Blackened and blown away.....	Vented at both ends.
347	.....	J	100	14.7	None.....	None.....	.....do.....	Vented at one end.
348	.....	.....	100	22.1	...do.....	...do.....	.....do.....	Vented at both ends.
141	.....	.....	200	19.3	Light.....	...do.....	No effect.....	Vented at one end.
142	.....	.....	200	16.1	None.....	...do.....	.....do.....	Do.
143	.....	.....	200	18.2	...do.....	...do.....	.....do.....	Do.
144	.....	.....	200	21.4	...do.....	...do.....	.....do.....	Do.
145	B–31	.....	200	21.4	...do.....	...do.....	.....do.....	Do.
146	.....	.....	200	26.8	...do.....	...do.....	Scorched at indicator.....	
326	.....	.....	200	13.9	...do.....	...do.....	Blackened.....	
289	.....	.....	400	110.0	Medium..	...do.....	No effect.....	Do.
290	B–56	R	400	51.4	None.....	...do.....	.....do.....	
291	.....	R	400	64.2	...do.....	...do.....	.....do.....	
292	.....	.....	400	51.4	...do.....	...do.....	.....do.....	
293	.....	.....	400	51.4	...do.....	...do.....	.....do.....	

TABLE 9—Continued

Record of Fuse Short-Circuit Test, Chicago, Ill., September–October, 1915—Continued

SECOND CIRCUIT CONDITION, 600 VOLTS—Continued

No. IV Fuses

Fuse No.	Film No.	Stock	Fuse rating	Kw-sec.	Behavior			Remarks
					Noise	Flash	Cotton	
241	B-48	R	30	3.2	None	None	No effect	Cartridge moist.
242			30	3.2	do	do	do	Do.
243			30	3.2	do	do	do	Do.
244			30	3.7	do	do	do	Do.
245		R	30	3.2	do	do	do	Do.
246		R	30	4.3	Light hiss	do	Scorched at indicator	Do.
387		R	30	3.4	None	do	Scorched at cap	Do.
388			30	3.6	do	do	No effect	Cartridge moist. Vented at one end.
389			30	3.6	do	do	do	Do.
247			60	11.8	Light hiss	do	do	Vented at both ends.
248			60	8.6	do	do	Scorched at indicator	Do.
249			60	9.6	do	Mild	No effect	Do.
250			60	8.6	do	None	do	Do.
251		R	60	9.6	do	do	do	Do.
252	B-49		60	8.6	None	do	do	Vented at one end.
375			60	9.6	do	do	Blown away	Do.
376		R	60	9.6	do	do	do	Vented at both ends.
377		R	60	9.6	do	do	Moistened	Cartridge moist. Vented at both ends.
253		R	100	16.0	Light hiss	do	Blown away	Cartridge moist.
254			100	17.1	do	do	do	Do.
255	B-50	R	100	19.3	do	do	do	Do.
256			100	17.1	do	do	do	Do.
257			100	16.0	Light	Mild	No effect	Do.
258			100	17.1	None	None	do	Do.
349		R	100	20.3	do	do	do	Do.
350		R	100	19.3	do	do	do	Do.
259			200	36.4	Light	do	Blown away	
260			200	32.1	do	do	No effect	Do.
261	B-51		200	32.1	do	do	do	Do.
262			200	27.8	do	do	do	Do.
263			200	32.1	do	do	do	One cap started. Cartridge moist.
264		R	200	37.4	do	do	Blown away at one end	Cartridge moist.
332		R	200	26.8	do	do	No effect	
333			200	25.7	do	do	Blown away	
306			400	96.3	Loud hiss	do	No effect	Filler blown out and cartridge moist.
307		R	400	69.5	do	do	do	Do.
308	B-59		400	107.0	do	do	do	Do.
309		R	400	107.0	do	do	do	Do.
310			400	112.0	do	do	Blown away at indicator	Do.

147	B-32		30	3.2	None	None	No effect	
148			30	6.4	do	Mild	do	
149			30	3.2	do	None	do	
150			30	4.3	do	Mild	do	
378		J & R	30	7.9	Light	None	do	
379		J & R	30	5.5	do	Mild	Ignited	
380		J & R	30	6.3	do	do	Blackened	
151			30	4.3	None	Bright	Scorched at indicator	
152			30	4.3	do	None	No effect	
153			60	11.8	do	Mild	do	
154			60	10.7	Light	Bright	Scorched at indicator	
155	B-33		60	15.0	None	None	No effect	
156			60	10.7	Light	Medium	Scorched at indicator	Vented at one end.
157			60	8.6	do	Mild	No effect	
158			60	10.7	None	None	do	
352		J	60	16.1	Medium	Bright	Ignited and blown away	One cap blown off. Bent clip.
353		J	60	15.0	do	Medium	Blown away	Do.
354		J & R	60	14.3	do	do	do	Do.
355		R	60	11.8	do	do	do	
356			60	11.1	do	do	Blackened at indicator	Vented at one end.
357		R	60	11.8	Loud	do	Blown away	One cap blown off. Bent clip.
159			100	23.6	Medium	Mild	Blackened	Vented at one end.
160			100	19.3	do	do	Blackened and blown away at one end	Do.
161			100	23.6	None	None	No effect	
162	B-34		100	17.1	do	do	do	Do.
163			100	21.4	Light	do	do	Do.
164		R	100	19.3	Medium	Medium	Scorched at one end	Vented at both ends.
342		R	100	20.6	do	Mild	Scorched at indicator	Do.
343		J & R	100	46.0	Loud	Bright	Ignited	Hole fused in cap next to blade. Vented at both ends.
344		J & R	100	23.6	Light	None	Scorched at indicator	
165			200	87.8	None	Mild	Scorched at one end and indicator	Vented at both ends.
166			200	61.0	do	Bright	Ignited	Do.
167	B-35		200	56.6	Light	Medium	Scorched	Do.
168			200	34.2	do	Mild	Blackened	Vented at one end.
169			200	46.0	do	Medium	Ignited	Do.
170			200	46.0	do	None	No effect	Vented at both ends.
321		J	200	53.5	Medium	Very bright	Ignited	Vented at one end.
322			200	49.2	do	Bright	do	Vented at both ends.
323		J	200	27.8	Long hiss	None	No effect	
324		R	200	56.7	do	Bright	Ignited	Vented at one end.
325		R	200	35.3	do	do	Blackened and blown away	Vented at both ends.
331		R	200	60.0	Hiss	do	Blackened	Do.
439	B-66		200	46.5	do	Mild	No effect	Vented at one end. Cartridge moist.
294			400	139.0	Light	Bright	Blown away	Vented at both ends. Cartridge very moist.
295		R	400	139.0	do	do	do	Cartridge very moist and blade loosened in cap.
296			400	107.0	do	do	do	Vented at both ends. Cartridge moist. Did not indicate.
297			400	98.4	do	do	Ignited	Do.

TABLE 9—Continued

Record of Fuse Short-Circuit Test, Chicago, Ill., September–October, 1915—Continued

SECOND CIRCUIT CONDITION, 600 VOLTS—Continued

Economy Fuses [a]

Fuse No.	Film No.	Stock	Fuse rating	Kw-sec.	Behavior			Remarks
					Noise	Flash	Cotton	
265	B–52		30	3.7	None	None	No effect	
266			30	3.2	do	do	do	
267		R	30	3.3	do	do	do	
268			30	3.3	do	do	do	
269			30	3.3	do	do	do	
270		R	30	3.3	do	do	do	
390		J	30	3.0	do	Mild	do	
391		J	30	2.8	do	None	do	
392		J	30	3.2	do	do	do	
271	B–53		60	5.9	Violent	Bright	Ignited	One screw plug blown out. Bent clips.
272			60	4.9	None	None	No effect	
273			60	59.4	Violent	Bright	Ignited	Fiber shell shattered. Bent clips.
274			60	5.7	None	None	No effect	
275			60	6.4	Very light	do	do	
276			60	5.6	None	do	do	
402			60	5.3	Violent	Bright	Blown away	
403	B–63		60	5.9	do	do	do	One screw plug blown out.
277	B–54		100	9.6	do	do	Ignited	One screw plug blown out. Bent clips.
278			100	8.6	do	do	do	Half of fiber shell shattered. Bent clips.
279			100	9.6	do	do	do	One screw plug blown out. Bent clips.
280			100	8.6	do	do	do	Both screw plugs blown out. Bent clips.
281			100	9.6	do	do	do	One screw plug blown out. Bent clips.
282			100	9.2	do	do	do	Both screw plugs blown out. Bent clips.
283	B–55		200	16.0	Medium	do	do	Do.
284			200	12.8	Loud	do	do	Outer brass washer, but not blade, blown out.
285		R	200	20.3	do	do	do	Started outer brass washer at one end.
286			200	17.1	do	do	do	Do.
287			200	17.1	do	do	do	
288			200	184.0	do	do	do	Do.
334		R	200	12.8	do	do	do	Leather and outer brass washer blown out at one end.
335		R	200	18.2	do	do	do	
316			400	16.0	None	do	do	
317			400	21.4	Medium	None	No effect	
318			400	15.0	Light	do	do	
319			400	150.0	Medium	Very bright	Ignited	Fiber shell blown out one side, carbonizing opening.

320	B-61	R	400	15.0	None	None	Blackened	
440			60	5.9	do	do	No effect	
441			60	5.9	do	do	do	
442			60	5.7	do	do	do	
443			60	5.9	do	do	do	
444			60	5.9	do	do	do	One screw plug blown out.
445			60	5.8	Violent	Bright	Ignited	Do.
446			60	5.7	do	do	Blown away	Do.
447			60	6.0	do	do	do	Do.
448			60	5.9	None	None	No effect	
449			60	6.1	do	do	do	
458			100	9.9	Medium	Mild	do	
457			100	9.5	do	None	do	Bent clips.
459			100	9.9	do	do	do	Do.
460			100	9.9	Loud	Bright	Ignited	
461			100	10.1	do	do	do	
462			100	9.6	do	do	do	
463			100	9.6	do	do	do	
464			100	10.0	do	do	do	
465			100	10.0	do	do	do	
466			100	10.1	do	do	do	
450			200		None	None	No effect	
451			200	11.2	Medium	do	Ignited	
452			200	15.8	None	do	No effect	
453			200	17.8	do	do	do	
454			200	17.8	Loud	Bright	Ignited	
455			200	17.8	None	None	No effect	
456			200	17.2	Violent	Bright	Ignited	Knife blade and washers blown out as a unit. Sheared brass cap.

No. VI Fuses

171			30	4.3	None	None	Scorched at indicator	
172	B-36		30	3.2	do	do	do	
173			30	3.2	do	do	do	
174			30	4.3	do	do	do	
175			30	4.3	do	do	do	
176			30	3.2	do	Mild	do	
384		R	30	3.7	Light	None	Scorched	Did not indicate.
385		R	30	3.9	do	Mild	No effect	
386		J	30	3.3	do	do	Scorched at indicator	
177			60	10.7	None	None	do	
178	B-37		60	12.8	do	do	No effect	Do.
179			60	10.7	do	do	Scorched at indicator	
180			60	10.7	do	do	No effect	
181			60	10.7	do	do	do	
182			60	16.0	do	do	do	
364		J	60	12.3	do	do	Scorched at indicator	

[a] The fuses groped under this heading numbered 440 to 456 were submitted as special fuses of normal size but provided with heavier caps.

TABLE 9—Continued

Record of Fuse Short-Circuit Test, Chicago, Ill., September–October, 1915—Continued

SECOND CIRCUIT CONDITION, 600 VOLTS—Continued

No. VI Fuses—Continued

Fuse No.	Film No.	Stock	Fuse rating	Kw-sec.	Behavior			Remarks
					Noise	Flash	Cotton	
365	.....	J	60	11.8	None	Mild	No effect	Vented at one end. Did not indicate.
366	.....	J	60	11.8	....do	None	Scorched at indicator	Vented at one end.
367	.....	J	60	12.4	....do	....do	No effect	
368	.....	.....	60	10.5	....do	....do	.....do	
183	B–38	.....	100	10.7	....do	....do	Scorched at indicator	
184	.....	.....	100	11.8	....do	....do	No effect	Cartridge moist.
185	.....	.....	100	12.8	....do	....do	Scorched	
186	.....	.....	100	12.8	....do	Mild	No effect	Do.
187	.....	.....	100	10.7	....do	None	Scorched at indicator	Do.
188	.....	.....	100	11.8	....do	Mild	.....do	Do.
339	.....	J	100	12.0	Light	....do	Blackened	
340	.....	J	100	11.9	....do	....do	.....do	Did not indicate.
341	.....	J	100	12.0	None	None	No effect	Do.
122	B–25	.....	200	62.0	Medium	....do	Blackened	Vented at one end.
189	.....	.....	200	81.3	Loud hiss	....do	Blown away	Vented at both ends.
190	.....	.....	200	37.4	None	....do	No effect	Cartridge moist.
191	.....	.....	200	59.0	Loud hiss	Mild	Blown away	Vented at both ends.
192	B–39	.....	200	36.4	None	None	No effect	Cartridge moist. Vented at one end.
193	.....	.....	200	62.0	Medium	Mild	.....do	Vented at both ends.
194	.....	.....	200	45.0	Loud	Medium	Blown away	Do.
327	.....	.....	200	47.0	....do	None	.....do	
328	.....	.....	200	55.7	....do	Bright	Scorched at indicator	Do.
121	B–26	.....	400	.....	Medium	None	Blackened	Filler blown out at both ends.
298	.....	J	400	97.4	Loud	Medium	No effect	Do.
299	.....	.....	400	90.0	....do	....do	.....do	Do.
300	.....	.....	400	87.8	Medium	Mild	.....do	Do.
301	.....	.....	400	99.5	Loud	Medium	Blown away	Cartridge moist. Filler blown out at both ends.
302	B–57	.....	400	100.5	....do	....do	.....do	Do.
303	.....	.....	400	65.2	....do	....do	.....do	Filler blown out at both ends.
404	B–64	.....	400	143.6	....do	None	No effect	Indication doubtful.

An examination of Table 10 will show that in both series of tests the performance of Economy fuses in the knife-blade type proved in general inferior to that of all makes of approved fuses, judged on the relative percentage of failures. However, one type of approved fuse gave rise to three cases of what was considered to be the most serious type of failure, namely, the remaking and sustaining of the circuit after it had first been opened by the fuse. This type of failure did not occur in the Economy fuses, except in the single instance where the arc appeared to be held for a few tenths of a second; although the oscillograms showed that in a few cases there was a remaking of the circuit for a few thousandths of a second.

In the ferrule types tested in these two series there was not much choice between the Economy fuses and several makes of approved fuses, although three types of approved fuses were distinctly superior to the Economy fuse. In the 60-ampere size the Economy fuse behaved much worse than in others, while in the 30-ampere size it was distinctly superior to several makes of approved fuses and was the equal of any tested.

The following summaries of 600-volt fuse short-circuit test failures show the number of each type of fuse failure which occurred in each size tested. Six main divisions of failure are recognized:

A = Injury to cartridge fiber shell.
B = Blowing off of cap.
C = Injury to cut-out.
D = Ignition of cotton.
E = Holding or sustaining the arc.
F = Remaking of the circuit.

The fuses recorded failed under one of the two following short-circuit conditions:

First. A circuit having the limiting current rising from 10 000 to approximately 15 000 amperes, due to a gradual reduction in storage battery internal resistance during the period of test. The value of reactance was inappreciable, as conductors were tied together.

Second. The circuit as above, with added noninductive resistance to limit the current to 10 000 amperes and practically constant battery internal resistance.

In some instances fuses developed more than one kind of failure, making the total number of fuses which failed less than the number

of failures. The per cent of failures is the ratio of total failures to total fuses tested.

The spaces designated by "o" indicate that fuses were tested but no failures resulted under that division.

For other terms, see explanation accompanying short-circuit test data.

TABLE 10

Summary of Fuse Short-Circuit Tests, Chicago, Ill., September-October, 1915

(*a*) FERRULE TYPE FUSES

Make of fuse	Circuit condition	Failure						Number tested	Per cent failed	Per cent of failures
		A	B	C	D	E	F			
No. I	First	0	9	8	0	0	0	16	56	106
	Second	0	0	0	1	0	0	12	8	8
No. II	First	0	3	1	0	0	0	9	33	45
	Second	0	4	2	0	0	0	21	19	29
No. III	First	0	0	0	0	0	0	9	0	0
	Second	0	0	0	0	0	0	21	0	0
No. IV	First	0	0	0	0	0	0	7	0	0
	Second	0	0	0	0	0	0	18	0	0
No. V	First	0	1	1	1	0	0	11	18	27
	Second	0	4	4	2	0	0	21	24	48
Economy	First	0	3	1	1	0	0	15	20	33
	Second	1	7	3	3	0	0	27	30	52
No. VI	First	0	0	0	0	0	0	6	0	0
	Second	0	0	0	0	0	0	20	0	0

(*b*) KNIFE-BLADE TYPE FUSES

No. I	First	0	0	0	0	0	0	7	0	0
	Second	0	0	0	0	0	0	14	0	0
No. II	First	0	1	1	0	0	0	6	17	33
	Second	0	0	0	3	1	3	21	24	33
No. III	First	0	0	0	0	0	0	6	0	0
	Second	0	0	0	0	0	0	22	0	0
No. IV	First	0	0	0	0	0	0	3	0	0
	Second	0	0	0	0	0	0	21	0	0
No. V	First	0	0	1	2	0	0	6	50	50
	Second	0	0	0	7	0	0	26	27	27
Economy	First	0	3	3	0	0	0	3	100	200
	Second	2	8	8	26	0	0	36	78	122
No. VI	First	0	0	0	0	0	0	12	0	0
	Second	0	0	0	0	0	0	26	0	0

TESTS ON AGED FUSES

As previously stated, a number of short-circuit tests were made on fuses that had carried their rated current for a considerable time, and these tests gave somewhat conflicting results. The details of these tests are given in Table 11.

TABLE 11

Record of Fuse Short-Circuit Test, Chicago, Ill., September–October, 1915

SECOND CIRCUIT CONDITION, 600 VOLTS

No. I Fuses [a]

Fuse No.	Film No.	Stock [b]	Fuse rating	Kw-sec.	Behavior			Remarks
					Noise	Flash	Cotton	
427			30	11.9	None	Mild	No effect	Solder melted at one end. Run 95 hours at 30 amperes.
428			30	9.2	do	do	do	Solder melted at both ends. Run 95 hours at 30 amperes.
429			30	12.4	Loud	Bright	do	Solder melted at one end. Run 95 hours at 30 amperes.
430			30	9.3	Medium	Medium	do	Solder melted at one end. Bent clips. Run 95 hours at 30 amperes.
413			60	9.9	Loud	None	do	One cap blown off. Run 95 hours at 60 amperes.
414			60	10.6	Medium	do	do	Do.
415			60	10.6	do	Mild	do	Do.
405			60	10.4	do	Medium	do	One cap blown off. Blown out of clips. Run 98 hours at 60 amperes.

No. II Fuses [a]

18			30	5.9	None	Mild	No effect	Filler blown out at one end. Run 98 hours at 30 amperes.
20			30	5.8	do	do	do	Vented at one end. Run 98 hours at 30 amperes.
396			30	4.6	do	None	do	Vented opposite indicator end. Run 98 hours at 30 amperes.
407			30	5.3	do	do	do	Run 98 hours at 30 amperes.
431			30	3.3	Light	do	do	Vented at one end. Run 95 hours at 30 amperes.
432			30	3.9	do	do	do	Run 95 hours at 30 amperes.
406			60	10.2	Violent	Medium	Blown away	Cap opposite indicator end blown off. Blown out of clips. Run 98 hours at 60 amperes.
408			60	9.9	None	None	No effect	Vented at one end. Run 98 hours at 60 amperes.
416			60	10.0	Medium	do	do	Run 95 hours at 60 amperes.
417			60	9.9	do	Mild	do	Vented at one end. Run 95 hours at 60 amperes.
418			60	9.9	do	None	do	Do.
419			60	9.9	do	do	do	Do.
420			60	10.1	Light	Mild	do	Do.

[a] These fuses had carried their rated current at the laboratories of the Bureau of Standards for an extended period, to determine the effect of aging under such conditions upon short-circuit performance.

[b] R=rated; J=taken from jobber's stock. Where no symbol is given the fuse was supplied by manufacturer.

TABLE 11—Continued

Record of Fuse Short-Circuit Test, Chicago, Ill., September–October, 1915—Continued

SECOND CIRCUIT CONDITION, 600 VOLTS—Continued

Economy fuses [a]

Fuse No.	Film No.	Stock	Fuse rating	Kw-sec.	Behavior			Remarks
					Noise	Flash	Cotton	
397	.....	.....	30	3.2	None	None	Blackened	Run 98 hours at 30 amperes.
398	.....	.....	30	3.2	Light	...do	...do	Do.
399	.....	.....	30	3.0	None	...do	...do	Do.
400	.....	.....	30	3.2	...do	...do	No effect	Do.
401	.....	.....	30	3.2	...do	...do	...do	Do.
433	.....	.....	30	3.3	...do	...do	...do	Run 95 hours at 30 amperes.
434	.....	.....	30	3.2	...do	...do	...do	Do.
435	.....	.....	30	3.2	...do	...do	...do	Do.
436	.....	.....	30	3.2	...do	...do	...do	Do.
437	.....	.....	30	3.2	...do	...do	...do	Do.
438	.....	.....	30	2.6	Light	Mild	...do	Do.
409	.....	.....	60	5.5	None	...do	...do	Run 98 hours at 60 amperes.
410	.....	.....	60	5.5	...do	None	...do	Do.
411	.....	.....	60	5.9	Violent	Bright	Blown away	One screw plug blown out. Run 98 hours at 60 amperes.
412	.....	.....	60	5.3	...do	...do	...do	Do.
421	.....	.....	60	5.3	...do	...do	...do	One screw plug blown out. Run 95 hours at 60 amperes.
422	.....	.....	60	5.9	Light	None	No effect	Run 95 hours at 60 amperes.
423	.....	.....	60	5.7	Violent	Bright	Blown away	Fiber shell shattered. Caps remained in clips. Run 95 hours at 60 ampers.
424	.....	.....	60	3.8	...do	...do	Ignited	Fiber shell shattered. Run 95 hours at 60 amperes.
425	.....	.....	60	6.4	...do	...do	...do	One screw plug blown out. Bent clip. Run 95 hours at 60 amperes.
426	.....	.....	60	5.7	None	None	No effect	Run 95 hours at 60 amperes.

250 VOLTS, LIMITING CURRENT 10 000 AMPERES

No. I Fuses [a]

536	.....	.....	30	.....	Light	Mild	Badly blackened	Run 75 hours at 30 amperes.

No. II Fuses [a]

514	.....	J	200	.....	None.....	None.....	Blackened.....	Run 51 hours at 200 amperes.

No. III Fuses [a]

501	.....	.....	30	.....	Light.....	Mild.....	Blackened.....	Run 98 hours at 30 amperes.
503	.....	.....	30	.....	...do.....	...do.....	Ignited at indicator.....	Run 95 hours at 30 amperes.
533	.....	.....	30	.....	...do.....	None.....	No effect.....	Run 98 hours at 30 amperes.
534	.....	.....	30	.....	...do.....	...do.....	Scorched at indicator.....	Do.
515	.....	.....	200	.....	None.....	...do.....	.....do.....	Filler blown out. Run 51 hours at 200 amperes.
520	.....	.....	200	.....	...do.....	...do.....	.....do.....	Run 51 hours at 200 amperes.

No. IV Fuses [a]

537	.....	.....	30	.....	Light.....	None.....	Scorched at ends.....	Run 95 hours at 30 amperes.
547	.....	.....	30	.....	...do.....	...do.....	Scorched at indicator.....	Run 98 hours at 30 amperes.

Economy Fuses [b]

508	.....	.....	30	.....	None.....	None.....	Blackened.....	Refilled once. Run 98 hours at 30 amperes.
509	.....	.....	30	.....	Light.....	...do.....	No effect.....	Refilled once. Caps started. Run 95 hours at 30 amperes.
510	.....	.....	30	.....	...do.....	...do.....	.....do.....	Refilled once. Run 95 hours at 30 amperes.
511	.....	.....	30	.....	...do.....	...do.....	Slightly blackened.....	Refilled once. Run 98 hours at 30 amperes.
529	.....	.....	30	.....	Loud.....	...do.....	No effect.....	Refilled twice. Run 98 hours at 30 amperes.
530	.....	.....	30	.....	Light.....	...do.....	Blackened.....	Refilled 22 times. Run 95 hours at 30 amperes.
531	.....	.....	30	.....	...do.....	...do.....	.....do.....	Refilled once. Run 98 hours at 30 amperes.
532	.....	.....	30	.....	...do.....	...do.....	.....do.....	Refilled twice. Run 95 hours at 30 amperes.
*548	.....	.....	30	.....	Violent....	Medium....	.....do.....	Fiber shell cracked longitudinally. Run 20 hours at 30 amperes.
*549	.....	.....	30	.....	...do.....	Bright.....	Ignited.....	Fiber shell shattered. Run 17 hours at 30 amperes.
*550	.....	.....	30	.....	Loud.....	...do.....	.....do.....	Fiber shell shattered. Piece of fiber broken away and fiber browned at one place before short circuit. Run 17 hours at 30 amperes.
*551	.....	.....	30	.....	None.....	...do.....	.....do.....	Fiber shell shattered. Fiber darkened before short-circuit test. Run 17 hours at 30 amperes.

[a] These fuses had carried their rated current at the laboratories of the Bureau of Standards for an extended period, to determine the effect of aging under such conditions upon short-circuit performance.

[b] These fuses had carried their rated current at the laboratories of the Bureau of Standards for an extended period (with the exception of those marked with an asterisk (*), which were aged and furnished by the D. & W. Fuse Co.), to determine the effect of aging under such conditions upon short-circuit performance. The Economy fuses have been refilled, as noted, after short-circuiting tests made at the laboratories of the Bureau of Standards.

TABLE 11—Continued

Record of Fuse Short-Circuit Test, Chicago, Ill., September–October, 1915—Continued

250 VOLTS, LIMITING CURRENT 10 000 AMPERES—Continued

Economy Fuses[a]—Continued

Fuse No.	Film No.	Stock	Fuse rating	Kw-sec.	Behavior			Remarks
					Noise	Flash	Cotton	
*552			60		None	None	No effect	Run 20 hours at 60 amperes.
*553			60		Loud	Bright	Ignited	Fiber shell blown out one side. Bent clips. Run 20 hours at 60 amperes.
*554			60		Violent	do	do	Fiber shell shattered. Bent clip. Run 20 hours at 60 amperes.
*555			60		do	do	Blackened	Fiber shell blown out one side. No label on fuse. Run 20 hours at 60 amperes.
556			60		Light	None	No effect	Run 10 hours at 60 amperes.
557			60		do	do	do	Run 98 hours at 60 amperes.
558			60		do	do	Slightly blackened	Do.
559			60		do	do	No effect	Do.
560			60		do	do	do	Do.
561			60		do	do	do	Do.
562			60		Medium	Bright	Ignited	One cap blown off. Run 98 hours at 60 amperes.
563			60		Light	None	No effect	Refilled once. Run 95 hours at 60 amperes.
564			60		Loud	Bright	Ignited	Refilled once. Fiber shell shattered. Bent clips. Caps very loose on shell before test. Run 95 hours at 60 amperes.
565			60		do	do	do	Fiber shell shattered at center. Run 95 hours at 60 amperes.
566			60		Light	None	No effect	Run 95 hours at 60 amperes.
512			200		do	do	Slightly blackened	Run 51 hours at 200 amperes.
513			200		Loud	do	Blackened	Do.
522		R	200		Medium	Bright	Ignited	Fuse No. 34 in Boston test. One cap blown off. Run 51 hours at 200 amperes.
523			200		do	do	do	One cap loosened and one cap blown off. Run 51 hours at 200 amperes.

No. VI Fuses[a]

506			30		None	Mild	Slightly scorched	Run 95 hours at 30 amperes.
535			30		Light	None	No effect	Do.

No. II Fuses								
500	.....	J	30	.....	Light.....	Mild.....	Blackened.....	
505	.....	J	30	.....	None.....	None.....	No effect.....	
No. III Fuses								
516	.....	.....	200	.....	Light.....	None.....	Scorched at indicator.....	
517	.....	.....	200	.....	...do.....	...do.....	.....do.....	
518	.....	.....	200	.....	...do.....	...do.....	.....do.....	
519	.....	.....	200	.....	None.....	...do.....	.....do.....	
No. IV Fuses								
504	.....	R	30	.....	Medium..	Mild.....	No effect.....	
538	.....	.....	30	.....	Light.....	None.....	Blackened at indicator.....	
539	.....	.....	30	.....	...do.....	...do.....	.....do.....	
[b] 540	.....	.....	30	.....	...do.....	...do.....	No effect.....	
[b] 541	.....	.....	30	.....	...do.....	...do.....	.....do.....	
[b] 542	.....	.....	30	.....	...do.....	...do.....	Scorched at indicator.....	
[b] 543	.....	.....	30	.....	...do.....	...do.....	.....do.....	
[b] 544	.....	.....	30	.....	None.....	...do.....	.....do.....	
[b] 545	.....	.....	30	.....	Medium..	...do.....	Blackened.....	
[b] 546	.....	.....	30	.....	Light.....	...do.....	Scorched at indicator.....	
Economy Fuses								
507	.....	.....	30	.....	Light.....	None.....	Blackened.....	Refilled once.
528	.....	.....	30	.....	Loud.....	Bright.....	Ignited.....	Refilled twice. Fiber shell blown out one side.
No. VI Fuses								
502	.....	.....	30	.....	Light.....	Mild.....	Blackened.....	
524	.....	.....	30	.....	None.....	None.....	No effect.....	
525	.....	.....	30	.....	Light.....	...do.....	Scorched at indicator.....	
526	.....	.....	30	.....	...do.....	Mild.....	.....do.....	
527	.....	.....	30	.....	...do.....	None.....	Slightly scorched at indicator.....	

[a] These fuses had carried their rated current at the laboratories of the Bureau of Standards for an extended period (with the exception of those marked with an asterisk (*), which were aged and furnished by the D. & W. Fuse Co.), to determine the effect of aging under such conditions upon short-circuit performance. The Economy fuses have been refilled, as noted, after short-circuiting tests made at the laboratories of the Bureau of Standards.

[b] Fuses supplied by Mr. Conant, and tested at his request.

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The first tests were made at Boston on Economy and D. & W. fuses supplied by the D. & W. Fuse Co. which had carried their rated current for a period of about 50 hours. Subsequently, some fuses were tested at Chicago after having carried their rated current for about 17 hours at the D. & W. laboratory. An examination of the table shows that the Economy fuses supplied by the D. & W. company, after having been aged in this way, gave a very bad performance and showed marked evidence of charring and weakening of the fiber, whereas the D. & W. fuses similarly treated showed no deterioration. The table also shows that Economy fuses subjected by the Bureau of Standards to their rated current for a period of from 95 to 100 hours showed no appreciable evidence of deterioration in the 30-ampere size. With the 60-ampere size the performance of these fuses was much worse than in the case of the new fuses, but the deterioration was by no means as great as in the case of the fuses supplied by the D. & W. Fuse Co. The difference in results was due no doubt, in part at least, to the difference in the grade of fiber used in the manufacture of the fuses, the difference frequently being clearly apparent on inspection. In addition to the fuses named above, four 200-ampere Economy fuses were tested after having been aged on rated current for 51 hours at the Bureau of Standards and two of these exploded violently. In all of the prior tests on new fuses there were no explosions in the 200-ampere size, so that this result indicates a decided tendency to deterioration in these larger fuses. It might be urged that four fuses is too small a number to use as a basis of judgment, and this might perhaps be true were it not for the fact that the examination of the fuse cartridges showed very definite and unmistakable tendencies toward charring of the fiber, although the fuses were all properly filled. The foregoing results indicate that the tendency of Economy fuses to deteriorate while carrying their rated current is much greater in the larger sizes than in the smaller, as would be expected because of the higher temperature developed. The deterioration in these fuses is also markedly greater than in the case of fuses using powdered filler, with which they were compared.

In a separate series of tests on 600-volt fuses, measurements of temperature of the fiber cartridges were made on several makes of fuses, including the Economy and four makes of approved fuses, while carrying their rated current. These tests were made on the 100-ampere cartridges and they showed that the Economy

fuses operate at a considerably higher temperature than the fuses containing powdered filler. This is no doubt largely responsible for the deterioration observed.

PRACTICAL SIGNIFICANCE OF FUSE TESTS

1. *General Conditions of Tests.*—The foregoing tests of fuses, while they include a number of tests made on low limiting currents, were for the most part made under test conditions prescribed by Underwriters' Laboratories, which require that the circuits shall be so arranged that the limiting current on short circuit will be 10 000 amperes; and further, they require that only a single fuse, rather than two in series, shall be tested on the voltage for which it is rated. Considerable discussion has arisen as to the reasonableness of tests of this character. In practice the majority of fuses, especially on 250-volt circuits, are used in such a way that on short circuit there are practically always two fuses in series, although exceptional cases may arise in which but a single fuse would be in circuit on 250 volts, and there are one or two cities in which this would be the prevailing condition because of the use of 250 to 500 volt three-wire systems. In general, it may be said to be extremely rare in practice that a single fuse is short-circuited, except on Edison three-wire systems or on three-wire single-phase systems, in which cases only half the voltage is impressed on one fuse. In this respect, therefore, the test conditions are much more severe than the voltage conditions that would usually prevail in practice. In the experiments just described, in which two fuses in series were blown on the rated voltage of the fuses, the operation of the Economy fuses was entirely satisfactory, although the limiting current was 10 000 amperes, as called for by the Underwriters' specifications. If, therefore, it could be shown that in practice 10 000 amperes would be the maximum current to which the fuses would be subjected, there might be good grounds for assuming that the requirement for testing only a single fuse in the circuit is too severe and not best adapted to show how the fuse would perform in actual service. It is probably true that in the majority of cases in practice the fuses are not called upon to open a perfect short circuit, there being usually a considerable amount of resistance in the circuit which makes the operation of the fuses much more certain and reliable. That this is not always the case, however, is shown by the tests described in the following section:

2. *Possible Short-Circuit Currents in Practice.*—In order to get some idea as to the limiting currents that might be expected under actual service conditions in case a short circuit should occur near the customer's cut-out, inquiries were made of a number of light and power companies regarding this point. It was found, however, that in every case those engineers whose judgment was considered at all reliable were unwilling to venture even a guess as to what the limiting current at various points on their distribution system might be, especially in the Edison three-wire networks, and the construction of these systems is such as to make a calculation extremely tedious and difficult. It was therefore decided to make tests in a number of cases to determine the order of magnitude of the currents that would be had under typical conditions. Two series of tests were made, one in a city of about 350 000 inhabitants and the other in a city of about 2 000 000 inhabitants. In the smaller city only a few tests were made in the heart of the Edison networks, where the maximum would have been expected, the majority of tests being made in outlying portions of the network, where relatively small currents would occur. In the larger city the tests were made in the heart of the Edison three-wire distribution system, the tests being made at points varying from one to six city blocks from the nearest power house. The tests were made by connecting a resistance grid across the cut-out terminals with an ammeter in series, a voltmeter across the cut-out and a switch arranged to open and close the circuit. When the switch was closed a current of about 300 amperes was taken, and at the instant of closing the drop in voltage at the cut-out was noted, and from this the current that would occur on dead short circuit at the cut-out could be readily calculated.

The results of the tests in the smaller city are shown in Table 12 and in the larger city in Table 13. It will be seen that in the first case there was but one point at which the limiting current would exceed 10 000 amperes; although at several places it approached this figure. As pointed out, however, only a few of these were so located that anything like the maximum current would be expected. In Table 13 is shown the results of the tests made in the larger city, and the territory covered here may be regarded as representative of a very large part of the Edison three-wire system in the larger cities. It will be seen from this table that at the great majority of the points at which tests were made the cal-

culated limiting current is very much in excess of the 10 000 amperes specified for the test circuit by the Underwriters' Laboratories. In one case nearly 90 000 amperes and in another over 100 000 amperes would have resulted from a severe short circuit.

TABLE 12

Regulation of 220-Volt Direct-Current Circuits

Test No.	Size of service conductors	Distance from generating or substation	Limiting short-circuit current	Test No.	Size of service conductors	Distance from generating or substation	Limiting short-circuit current
		Feet	Amp.			Feet	Amp.
1		100	2790	10	No. 6	200	4320
2	No. 10	100	1340	11	No. 6	100	6050
3	750 000 cir. mils.	1000	1 2600	12	500 000 cir. mils.	2500	6050
4	500 000 cir. mills.		7710	13	No. 6	2500	1970
				14	No. 6	4500	1330
5	No. 6	4500	1370	15	No. 6	1500	3740
6		5000	8650	16	No. 2	2500	2500
7	00	5000	3820	17	No. 2	3500	1290
8	No. 6	6000	2250	18	No. 6	4500	1370
9	No. 4	8000	500	19	No. 2	4000	1290

TABLE 13

Regulation Tests on D. C. Customers' Service; Edison 3-Wire System; Commonwealth Edison Co., Chicago, Ill., October, 1915

Test No.	Feeder tap		Distance to nearest substation (from blue print)	Calculated limiting current
	Size	Length		
	Cir. mils		Feet	Amp.
1	1-1 000 000	Short	150	26 200
2	3-2 000 000	...do	400	107 000
3	1-1 000 000	...do	1500	20 000
4	1- 500 000	...do	600	17 100
5	1- "0"	...do	1100	9800
6	1-1 000 000	...do	1300	13 200
7	1-1 500 000	80 feet	1100	25 500
8	2-1 500 000	75 feet	900	87 300
9	1-1 000 000	Short	2300	13 900
10	1-1 500 000	75 feet	3000	13 400
11	1- 200 000	Short	2350	9800
12	1- No. 0	...do	3400	8100
13	1- No. 6	...do	2600	6100

In general, the short-circuit currents in this test would be at least several times that specified by the Underwriters' specifications. These tests indicate that, as a matter of fact, the limiting current is determined almost exclusively by the resistance of the customers' service wires between the cut-out and the street manhole, the resistance of the three-wire distribution network being so low as to be almost negligible. It follows, therefore, that not only would the 10 000 amperes specified by the Underwriters' Laboratories be in many cases possible, but much more severe

short-circuit conditions might at times occur. Special tests that have been made by the Bureau of Standards on sample fuses in which the voltage and the current had been varied throughout wide limits usually showed that the severity of the operation of the fuses is, throughout a considerable range, determined mainly by the product of voltage and current, cutting the voltage in half being substantially compensated for by doubling the current. It would appear, therefore, that testing a single 250-volt fuse on its rated voltage with 10 000 amperes limiting current would be substantially equivalent in severity to testing two fuses in series on 20 000 amperes, which, as shown above, is the condition that might occasionally be realized in practice.

In view of these tests it can not be said, therefore, that the conditions imposed by the Underwriters are too severe to represent a condition that is likely to occur in practice with sufficient frequency to be important; and consequently failure of fuses on these tests can not be ignored on the ground that such conditions are abnormal.

3. *Effect of Inductance on Fuse Performance.*—An examination of Table 5, giving the results of the Boston fuse tests, as well as a number of special tests made at the Bureau of Standards, shows that the effect of inductance on the performance of fuses is very marked. Experiments made at the Bureau of Standards show that even where comparatively small short-circuit currents are used, amounting to only a few hundred amperes, if there be a high inductance in the circuit, such as might be frequently encountered, the performance of the fuses may be expected to be very bad. This factor has not been taken into account in the Underwriters' specifications for fuse testing, probably because of the lack of definite knowledge regarding values of inductance that would likely be encountered in practice. As a matter of fact, it is our understanding that the specifications of the Underwriters' are designed not so much to represent actual extreme conditions to which fuses may be subjected in practice, but rather to represent the present state of the development of the art of fuse manufacture, it having been shown that it is entirely practicable to meet these requirements without imposing any undue hardship on the fuse manufacturers, although the cost of maintaining this standard has not infrequently been complained of by fuse users. In view, therefore, of the large short-circuit currents that may at times be encountered, as shown by the preceding tests, and in view of the very pronounced effect of inductance and the relatively poor performance of fuses on highly inductive circuits even where the limit-

ing current is very small, it can not be said that the test conditions imposed by Underwriters' Laboratories are more severe, nor as severe, as certain conditions that might arise in practice.

OSCILLOGRAPH RECORDS OF FUSE TESTS[3]

1. *Description and Interpretation of Records.*—A large number of oscillograph records were taken of the voltage, current, and time characteristics of the fuses under test. In general, it was the aim to take from one to two oscillograms of each size and make of fuse tested. There are presented herewith a considerable number of these oscillograms, the aim being to give one oscillogram of each size and make of fuse where possible. There are a number of cases, however, where this could not be done because of failure to get a good oscillogram. In all of the oscillograms presented herewith there are three records shown, namely, current, voltage, and time, the latter being shown by a 60-cycle alternating-current wave. In all of the records of the Boston (250 volts) test the zero line of current and voltage coincide. In the Chicago tests (600 volts) the zeros of these waves are separate. The current and voltage waves are readily distinguishable from each other by their form. In the Boston tests the sequence of events is from right to left, as shown by the arrows in many instances, while in the Chicago tests the reverse is the case, the sequence of events being from left to right. No arrows are shown on the latter series of oscillograms. An examination of the oscillograms reveals a large amount of valuable information regarding the performance of the fuses. Some of this can only be obtained by a detailed study of the oscillograms. The following are some of the chief characteristics of the performance of the various fuses as shown by these oscillograph records.

1. A comparison of the oscillograms shows that in general the Economy fuse opens the circuit more quickly after the arc begins to form than any of the approved makes of fuses.

2. With the smaller fuses, below 200 amperes, it will be seen that the fuse blows before the current reaches a steady state, this being particularly true in the ferrule types. In the larger fuses, especially in the 400 and 600 ampere ratings, the current generally reaches practically its maximum value before the arc begins to form.

3. The time elapsing between the closing of the switch and the beginning of the arc is characteristic of certain makes of fuses and

[3] See Figs. 1–11 grouped at the end of this paper.

seems to be an important factor in the fuse performance. The time required for the formation of the arc in the various sizes and makes of fuses is shown in Table 14, the time given in each case being the average for the particular size and make and voltage of all of the oscillograms taken. It will be seen that the time required for the formation of the arc in the case of the Economy fuse is greater than that of several approved makes but less than that of certain others. In particular, it will be noted that fuse II requires, in both the 30 and 60 ampere sizes, a considerably greater time for the arc to form; and in this connection it is significant that the 30 and 60 ampere fuses of this make behaved the worst of all fuses tested, they being inferior on the whole to Economy fuses. The oscillograms seem to show that this is due in part at least to the slowness with which the arc forms, which in the smaller sizes of fuses makes it possible for the current to reach a higher value before the fuse operates, which, of course, would tend to increase the severity of the operation.

TABLE 14

Average Time Elapsing Between the Closing of the Circuit and the Starting of the Arc

(*a*) 250 VOLTS

Size of fuse in amperes	Economy	I	II	III	IV	V	VI
	Second	Second	Second	Second	Second	Second	Second
30	0.0022	0.0016	0.0034	0.00155	0.0028	0.0029	0.0030
60	.0043	.....	.0049	.0029	.0036	.....	.0032
100	.0065	.0050	.0096	.0075	.0061	.0085	.0056
200	.0115	.0096	.....	.0160	.0102	.0213	.....
400	.0258	.023	.068	.053	.037	.048	.021
600	.0366	.053	.....	.....	.....	.....	.053

(*b*) 600 VOLTS

30	0.0015	0.00167	0.00270	0.0012	0.00167	0.0012	0.0012
60	.0026	.0017	.0030	.0027	.....	.0023	.0019
100	.....	.0066	.0049	.....	.0043	.0042	.0053
200	.....	.....	.0225	.0178	.0129	.013	.0065
400	.....	.050	.....	.....	.....	.....	.0348

4. A remarkable feature of the oscillograms of the Economy fuses is the marked tendency toward the production of high-frequency oscillations. While there are usually small ripples in the voltage and current waves of the approved fuses, there are in the majority of the Economy fuses very pronounced high frequency harmonics. The frequency of these varies somewhat with the size of the fuse, but is of the order of a few hundred cycles per second. A calculation of the natural frequency of the circuit from its known constants shows that it is altogether too high to give rise to the oscillations here observed. This, and the further facts

that the frequency varies with the size of the cartridge and also that the oscillations are practically absent from the fuses using powdered filler, indicates that these oscillations are probably due to mechanical resonance, the frequency being the natural period of vibration of the fuse cartridge. Since the conductivity of the compressed gases in the cartridge during the fuse explosion is a function of the pressure, it will readily be seen that there is a definite tendency to set up oscillations of this character. These high-frequency oscillations are of considerable importance, as they may increase considerably the insulation strain on connected apparatus.

5. In general, it will be seen from the oscillograms that the circuit is opened within a few hundredths of a second, the time generally being longer for the larger fuses than for the smaller ones. There were a few cases, however, in which the operation seemed to be considerably prolonged. This was particularly true in oscillograms numbers 33, 66, and 67. In no case, however, is there a record of the arc having persisted for longer than 0.2 second, so that none of the oscillograms can be said to indicate holding of the arc. There was one case, which has already been mentioned, in which an Economy fuse appeared to hold the arc for a very definite though short interval accompanied by sustained oscillation; but no oscillograph record was obtained on this fuse. It will be seen that in the case of the Economy fuse there were several cases in which the arc was apparently extinguished and then remade for a very brief interval of one or two thousandths of a second and then extinguished again.

6. The oscillograms show that in all cases there is a very abrupt rise of current on closing the switch after which the current rises more slowly, according to what appears to be an exponential curve. It has been suggested that the shape of this curve is due to peculiarities of the battery performance; but this theory is not borne out by these curves. The calculations based on the measured constants of the circuit show that the gradual rise of current is due practically, if not entirely, to the self-inductance of the circuit, the sudden rise at the start being apparently a charging current in the leads beyond the oscillograph ammeter shunt.

7. The oscillograms showing the performance of two fuses in series show that under these severe conditions of test, the two fuses blow almost exactly simultaneously, so nearly so in fact that the voltage on each of the two fuses is substantially equal; and

this explains why the performance of two fuses in series is so markedly superior to that of a single fuse.

8. An examination of the oscillograms shows that in all cases there occurred just at the instant the arc was extinguished a definite reversal of current in the oscillograph circuit. This is due to the disappearance of the electric charge stored in the leads at the time the fuse blows when the voltage across the cut-out is above the normal voltage of the circuit. After the fuse blows and the voltage of the leads drops to the normal voltage of the supply, there would necessarily be a reversal of current in the circuit.

9. In the Chicago fuse tests it will be observed that in practically all cases there is at the instant of closing the switch a negative deflection of the voltmeter element of the oscillograph. In some cases this is very pronounced, amounting to as much as half the voltage of the battery. This is due to a high resistance ground on the battery.

SUMMARY OF RESULTS OF FUSE TESTS

A careful examination of the records of the tests above referred to shows that in general the performance of Economy fuses under the test conditions prescribed by the Underwriters' Laboratories was decidedly inferior to that of the majority of the makes of approved fuses with which they were compared. There was one notable exception, however, there being one make of approved fuse which in the ferrule type proved quite uniformly less satisfactory under test than the Economy fuse, and was but little better than the Economy fuse in most of the knife-blade sizes. The performance of the fuse of this make, however, was decidedly below the limit set by the Underwriters' Laboratories, a condition which may at times develop in any device which has once been approved. When such a condition is found to have developed, however, it is the practice of the Underwriters' Laboratories to demand that the device be brought up to standard on penalty of withdrawing approval if this is not done within a reasonable time. We understand that any new line of fuses performing as these fuses perform would not be approved by the Underwriters' Laboratories, and if such a performance should persist for a considerable time in any approved line of fuses the approval would be withdrawn. Further, the tests show that Economy fuses in service tend to deteriorate more rapidly than fuses using powdered filler, so that the comparison of old fuses would probably be still less favorable to

the Economy fuse. This is more important in a refillable fuse than in a nonrefillable fuse, because the former are likely to be kept in the customers' cut-outs for a longer time. It follows, therefore, that if Economy fuses were to be approved in view of their performance under these tests the result would be a distinct lowering of the standard of fuse performance as shown by short-circuit tests.

The foregoing tests, however, show quite clearly that it is entirely practicable from a manufacturing standpoint to manufacture fuses that will give very satisfactory performance under the tests imposed by the Underwriters' Laboratories, so that before changing the test requirements so as to lower the standard of fuse performance we should be definitely assured that on the one hand no serious hazard would result from so doing, or that any hazard which might be introduced would be fully justified by compensating advantages. The compensating advantages alleged for the Economy fuse are two in number, namely, first, that they reduce the cost of fuse maintenance to the user; and, second, that the ease with which they can be refilled by the user will in large measure reduce the tendency to dangerous misuse of approved fuses. Data bearing on these questions have been obtained by the Bureau of Standards in its investigations of the use of Economy fuses, and these data are presented in the following sections.

VI. INSPECTIONS OF FUSE INSTALLATIONS MADE BY THE BUREAU OF STANDARDS

INTRODUCTION

In addition to the tests made by the Bureau of Standards and the evidence submitted by the parties to the arbitration, it has been deemed necessary for the Bureau of Standards to send inspectors into the field to inspect a considerable number of representative fuse installations and confer in person with the users of fuses in order to obtain first-hand information regarding some of the points that have been brought into question by the investigation. A summary of the results of these inspections is presented in the following reports. On account of the detail involved these reports have been condensed as much as possible, smoothness and fullness having been in many cases sacrifiecd for brevity.

1. INSPECTIONS IN NEW YORK, N. Y.[4]

The purpose of this inspection was to obtain evidence of the prevalence in one large city of the practice of making proper or

[4] By W. J. Canada, an electrical engineer of this Bureau.

improper fuse replacements in the small manufacturing occupancies known as "sweatshops" and also in printing establishments.

From a list of sweatshops and printing establishments previously prepared the addresses of a number of occupancies were taken, most of which were later found to contain some motors. A number of other sweatshops were inspected as they were noted in passing through the streets of New York City. The entire sweatshop district is represented in the inspections made, which also cover both newer and older types of shops.

Attention was particularly given to fusing of motor circuits on which fuse replacements are, of course, more frequent than on lighting circuits.

SUMMARY OF INSPECTIONS

The inspections were made to include a check on the sizes of motors and number and size of lamps which were supplied by the circuits, and on the sizes of circuit wire and the size of all fuses for each circuit. Thirty-four establishments were inspected, including printing occupancies, so-called sweatshops and loft buildings, in the latter of which the inspections were extended only to the main circuit arrangements. The make of fuse and the type, cartridge plug and link were noted in each case, and also the amount of overfusing. Improper types of fuse replacements were also carefully noted. In many installations no fuse abuse of any kind was found. Careful records were made on all peculiar conditions and these are covered in the summary below, which is given as included in the original report.

In several buildings a glance was taken at other motor installations in different occupancies to determine if the fuse situation was in general the same, although time was not taken to check the exact size of the fuse and circuit wire. In all such cases (about a dozen) the fusing was found to be done with standard material.

Totals of Fuses Inspected

	Number	Fuses	Proper type	Improper type	Cartridge fuse clips used
Total occupancies checked	34	520	491	29	447
Printing occupancies checked	4	272	263	9	263
Loft building, main boards	3	113	93	20	71
Sweatshop occupancies	27	135	135	0	113

	Per cent of all occupancies	Per cent of all fuses	Per cent of improper replacements to all fuses	Per cent cartridge fuse clips to all others	Per cent plug fuse receptacles improperly refilled
Total occupancies	100	100	5.9	91	0
Printing	12	52	3.4	100	0
Loft building	9	22	21.0	76	0
Sweatshop	79	26	0.0	85	0

INQUIRIES OF DEALERS

1. A small firm in the old sweatshop district, catering particularly to the sweatshop trade, with small motors, fans, etc. Their representative did not at first know what cartridge fuses meant, handles only plug fuses, and apparently had no idea what a refillable fuse would be. Personal call made on this concern.

2. A small concern, dealing mainly in repair work on fans and small motors in the sweatshop district. Upon request for refillable fuse, this firm did not understand what was meant. They handle mostly plug fuses. Such cartridge fuses as they handle come from a large drawer which contains loose a number of sizes and types of terminals. Upon pressing inquiry for refillable fuses, the representative of this firm stated that he "guesses that the kind you refill aren't any good or we would have heard of them."

5. Upon inquiry by telephone, another company stated that they refill all makes of cartridge fuses, sometimes using the old filling material and sometimes not. They also sell new fuses, but make none. They further stated that their refilled fuses blow just as well as the original one. Several firms do refilling of cartridge fuses as a business.

NOTES IN CONNECTION WITH INSPECTIONS

The term "sweatshop" is rarely used, has largely lost its meaning, and is to a great extent replaced by the term "loft." A loft building may have a floor area anywhere from 25 by 100 to 200 by 200 feet or more, the smaller size being the most prevalent. The height may vary from 5 to 12 stories, with a tendency toward the higher buildings. The separate lofts (formerly called, probably with justice, sweatshops) are located each on a separate floor and comprise sewing occupancies usually on light and highly inflammable materials, with closely grouped sewing machines, usually group driven but sometimes with individual drives with circuits carried over or under the machines. Where group drives are used, the motor will be started usually by the foreman, with individual drives by the operator, three times out of four a woman. The number of motors will vary; with group drives, from 1 to 10; probably in 90 per cent of such occupancies, not over 2; with individual motor drives the number will, of course, be much larger. With individual drives fusing will be done only at fuses on ceilings or in cabinets on side walls, and the blowing of fuses by the loads in small individual motors appears to be quite rare, since a 10 or 15 ampere fuse protecting a No. 14 circuit wire will overfuse a one-tenth horsepower motor 500 to 1000 per cent.

From consideration of the original low cost of installation, and the ease of removing an occupancy from one of the "power" buildings, the motor installations are protected in probably 90 per cent of the cases by plug fuses rather than by cartridge fuses. Such fuses are rarely placed in cabinets, owing to the fact that this is not required by either the ordinances or by the Underwriters. The building wiring itself usually has fuses in cabinets.

From the inspections made no tendency toward improper re-fusing was observable in this character of risk. This apparently results from two or three causes. First, because the motors are small and the fuse which protects the wire running to them, usually No. 14, is larger than necessary for the normal load demand of the motor. Second, because of the character of the load. Third, because of frequent inspections by Underwriters, factory inspectors, and others.

The case of the printing establishments is somewhat different. In a talk with the engineer of a lithographing company, he stated that this firm is adopting the use of circuit breakers as rapidly as possible, since fuses will be abused in order that service may be as continuous as possible, especially when men are on piece work, and it is very difficult to detect overfusing without much more time spent in inspection than is necessary with circuit breakers, which can be so used as to quickly restore service and yet readily indicate to the inspector when set too high. This firm claims to have tried every fuse available over a long period of years and to have arrived at this decision as a matter of its own experience. The engineer expressed it as his opinion that the Underwriters are lax in not requiring circuit breakers instead of fuses in such cases.

This engineer advised of a case where an Economy fuse had taken fire due to loose contact between the fuse element and the washer where bent over the washer. They have used many Economy fuses and find them not to solve the problem of motor protection.

CONCLUSIONS

From consideration of the results of the inspections described above it seems that the tendency to replace fuses by too large fuses or by improperly refilled fuses is very small among New York lofts (sweatshops) and, in fact, the frequency with which replacement of fuses becomes necessary appears very small. As compared with printing establishments and the main power boards of buildings where attended to by an electrician or a janitor, the tendency toward improper re-fusing in sweatshops appears almost negligible.

In the city of New York it has been permissible for some time to install refillable fuses in locations where they would be under the care of a competent and authorized electrician. Their sale has apparently not extended considerably into buildings in the sweatshop district or among printing establishments.

The janitors of loft buildings, however, appear somewhat accustomed to improper replacements of approved cartridge fuses, and in the printing establishments the use of approved fuses refilled by elements of unknown capacity and not subject to easy inspection is evidently rather large.

The natural conclusion to be drawn from the results of these inspections is that the tendency to improperly re-fuse circuits in sweatshops is too small to constitute a serious argument either for or against the use of a refillable fuse in these occupancies. The first cost of fuses appears to be more of a factor than the cost or convenience of refilling.

In the fuse boards subject to attendance by building janitors, on the other hand, there seems a marked tendency to improperly replace blown fuses. The makeshifts frequently used are probably fully as bad as would be the improper refilling of a refillable fuse. In most cases of improper replacements the fuse wire was left exposed (not within a cartridge). With a refillable fuse the cartridge protection might more often be used if refilled with the elements designed for the purpose.

In printing occupancies some tendency toward hasty replacements of fuses exists and the use of other than the standard fuses is considerable. Some firms regularly use refilled nonrefillable fuses which are of unknown capacity when so refilled. Others use jumpers. The larger concerns find that motor protection is better secured by breakers. The makeshifts frequently used are probably as bad as would be the improper filling of a refillable fuse, and jumping with copper would be no more frequent than at present.

INSPECTIONS IN NEW YORK, BROOKLYN, NEW HAVEN, AND BRIDGEPORT

Careful inspections [5] were made of a number of large and of moderate-sized manufacturing plants and mercantile establishments, and information was obtained from the chief engineers, electrical engineers, or electricians to determine the experience of these companies with fuses for their electrical circuits and their opinions based on this experience of the fuses which they have used.

The list of concerns selected was chosen from a large number of users of fuses in the cities of New York, Brooklyn, New Haven, and Bridgeport. From these the occupancies inspected were

[5] By W. J. Canada, an electrical engineer of this Bureau.

chosen with some regard to concerns most likely to have recorded their experience and also to have had very considerable experience. Consideration was also given to selecting large manufacturing plants, department stores, and small manufacturing plants.

In the inspections and conferences an effort was made to bring out the entire experience of the company over a considerable period as well as to ascertain the real opinion of the engineer. Effort was also made to reach the individual most closely concerned and familiar with the fuse situation. The results of these inspections are given below, and show in general a somewhat limited demand, use, and indorsement of the Economy fuse even among those concerns which regularly use them. In general, little abuse of nonrefillable fuses was found among this class of fuse users. Details of the inspections follow.

1. A group of office buildings in Brooklyn, N. Y., with a chief electrician and six others in charge. Fuses are replaced by electricians only on feeders and hall lights; tenants replace their own fuses. Two hundred and fifty to three hundred fuses are in use. No troubles have developed with standard new fuses except a few bad contacts with the knife-blade type. No refilled fuses are in use. Tests are made to see if the rating is correct. Weekly inspection, which includes the tenants' premises, is made by fire underwriters. Two tenancies were inspected, one a mattress factory in which, out of 10 fuses, 1 cut-out was found bridged with copper wire. The second had some Union fuses refilled at the factory which gave good results and were said to be very close to rating.

2. A lead manufacturing company in Brooklyn, N. Y., has two electricians in charge. Fuses are replaced by the electricians and by foremen of departments. Sometimes such fuses are refilled at the cut-out. Eight hundred cartridge fuses are in use, 400 of which are of the Economy make. Two hundred link fuses are in cabinets and sump motor fuses bridged with fuse wire are used to care for starting current. In this case no cabinet was used. Trouble has been experienced with old Economy fuses by the screws loosening, due to inelasticity of the fuse element and shrinkage of the fiber shell. They are said to blow too often. As far as known, refilled Economy fuses are properly rated and safe on short circuit. Thirty per cent of motor fuses are replaced annually, and 500 per cent at the switchboards having motor feeders, apparently on account of high temperature and close rating. Foremen are held responsible for filling material and correct size of link for the motors under their charge. The engineer greatly prefers circuit breakers and will install them as fast as the company will stand the expense. A sump motor circuit has fuse holders too small to take any standard fuse. A sample refillable fuse of another manufacture, the Fuseguard Co., was found. This company's idea is to use ordinary lead wire in refilling this fuse if it is safe to do so.

3. A group of 10 loft and 10 individual buildings has one chief and 20 assistant electricians in charge. Fuses are replaced only by electricians. Fifteen hundred fuses are under their control. There are 2200 fuses in the tenants' occupancies. One hundred circuit breakers are used. One thousand link fuses are in cabinets. They are using 50 new type Economy fuses for experimental purposes. They find that contacts in these fuses are bad when refilled so that fuses blow under load, and encourage bad filling, it taking too long a time for inspectors to check this. Refilled Economy fuses were sometimes overloaded. Principally motor fuses are replaced, about 300

annually. Probably sell 200 renewals per year to tenants. Do not prefer Economy fuses and dislike to use them because of the extra trouble, unwarranted by experience, and the temptation to improper refilling, particularly setting bad example to tenants. The fact that full approval is not given to Economy fuses by the Underwriters is considered important. Where a competent man is always on the ground, they believe a safe refillable fuse (not the Economy) may be an advantage. Fuses are an inconsiderable expense considering the amount of property and load involved. Inspection of two tenancies resulted in the finding of two refilled fuses (G. E. Inspection Co.). Cabinets are used for link fuses, but the others are mostly in the open. They dislike the G. E. Inspection Co.'s fuses. Warnings have been general enough to prevent refilling by the tenants.

A sugar refinery in Brooklyn, N. Y., employs 1 chief and 60 assistant electricians. The fuses are replaced only by electricians and refilled only at the stock room. They use 2500 cartridge fuses, of which 650 are Economy fuses. One hundred and fifty link fuses are in cabinets. Their experience with old Economy fuses has not been extensive. They had lots of filler on hand and used this with a few of the new type. No one but electricians ever refill. Frequency of blowing is not serious. Links are sometimes broken when being bent into place, but they do not consider this serious. No trouble experienced by loosening of contacts. One Economy fuse blew the end off. They dislike the indicator of approved new fuses, as it is regarded as a probable cause of fire. Among the standard fuses refilled by the manufacturer one J. M. exploded several years ago. At the present time manufacturers refill standard packages of fuses returned to them. Such fuses are considered satisfactory and are apparently properly rated and safe on short circuit. Circuit breakers are usually in series with motor circuits having short circuits. The refilled Economy fuses are apparently properly rated and safe on short circuit. They do not prefer the Economy fuses except that thay save a certain amount of expense, but might use more if the Underwriters did not object.

They prefer breakers where possible, but these sometimes stick and fuse protection is needed in addition. Where in series with the breaker the latter operates to save the fuse from blowing. This concern makes daily inspection of motors. Some Economy cartridges are made up for plug fuses on special orders. The engineer likes link fuses in cabinets.

4. A certain large office building in New York City has a chief electrician and six assistants. Fuses are replaced only by the electricians. About 6660 cartridge fuses are used and 60 copper links on the switchboard. They use 180 copper link fuses in cabinets on the feeders. No experience has been obtained with the Economy fuse.

They think that with different sizes of fuse the wrong element might probably be used. Indicators are considered unreliable on the approved new fuses, but no other trouble has been experienced. Refilled fuses are not used. About 500 ten-ampere cartridges are replaced annually, mostly on account of gas-filled lamps arcing across terminals. Annually blow 1500 fuses on ordinary lighting circuits. The Economy fuse might be an advantage, but they prefer to take no chances with a device not fully approved.

It would take three years for the Economy fuses to be a paying investment if the initial cost were three times as much as that of nonrefillable fuses. They would not pay on motor circuits. On nitrogen lamp circuits they would save their cost annually. Conditions here are all unusually good and records unusually well kept.

5. A large department store in New York City employs six electricians. Fuses are replaced only by electricians and refilled only at the stock room. There are 1700 cartridge fuses in use, of which 370 are Economy fuses. Some of these have been found to be improperly refilled. Experience has been obtained with the new Economy fuses. They did not like the old kind and did not use them. No troubles have developed in the new type. They have used fuses refilled by contractors who for all

they know may have used copper fuse wire. This was found to be so on inspection. These approved types of refilled fuses have not been properly rated, but apparently are giving no trouble. The refilled Economy fuses are properly rated and safe on short circuit. They replace 1500 fuses a year, mostly on motor circuits due to bad starting; have begun to use circuit breakers in some places. They prefer the Economy fuses on both lighting and motor circuits, as they represent economy in the long run, even if this takes some years. When other types are blown they expect to replace them with Economy fuses.

They have given very little consideration to the fuse question, because fuse troubles have been so infrequent.

6. A large department store in New York City has one chief and five electricians. Fuses are replaced only by electricians, and are refilled at the stock room. About 5400 cartridge fuses are in use, of which 200 are Economy fuses; 400 link fuses are used on the switchboard. Their experience with old Economy style of fuses shows that the screw thread loosens and the fuse blows under load. No trouble has been experienced with approved new fuses. They consider that refilled approved fuses cost too much and are not reliable. They have had no experience with approved type refilled fuses. Refilled Economy fuses are considered to be properly rated and safe on short circuit. Twenty per cent of lighting fuses and 100 per cent of motor fuses are refilled annually. They did not prefer the Economy fuse and do not use more of them because they believe that positive contact with solder is best, and as a result of considering the cost of the time consumed in refilling, especially in small quantities, they believe they are not economical. They do not use the Economy fuse on lighting circuits because of blowing under load. A saving of $24 per year by 15-ampere renewal links after the first year is effected by using Economy fuses on motor circuits.

7. A large store handling men's furnishings in New York City employs three electricians. Fuses are replaced by electricians only, and are refilled only at the stock room. They use 3612 cartridge fuses, of which 406 are Economy. One hundred link fuses are used on the switchboard. Their experience with new Economy fuses leads them to believe that they should be stamped with the rating on the ferrule. Approved new fuses sometimes flash at the indicator and injure persons. The indicator is not reliable. They do not have any trouble with approved type refilled or bridged fuses, but find the cost of refilling nearly as much as that of an approved fuse. Refilled fuses are not satisfactory and they have not recently returned fuses to the manufacturer for refilling. They believe Economy fuses are properly rated and safe on short circuit. They have on hand 1000 renewals, including 400 Economy casings and 600 Economy links. They prefer the Economy fuses and are replacing other types as fast as they blow.

8. A large furniture store in New York City employs three electricians. All fuses are replaced only by electricians, so that the trouble causing blowing can be found. Ten cartridge fuses are used, and 50 link fuses in cabinets are used on motor circuits. On lighting circuits there are 750 link fuses used in cabinets. No experience has been had with Economy fuses. No troubles have been met in the use of the approved fuses. About 30 fuses are renewed annually, mostly links in the 10-ampere lighting circuits. Do not use Economy fuses, as the present fuses are entirely satisfactory.

Fuse trouble presents no problem whatever. At the warehouse 1000 cartridge fuses are used. A few Economy fuses were used, but were ordered out by the Underwriters' inspector. This company thinks this action was very proper, on account of the danger of improper refilling.

9. A large hotel in New York City employs 12 electricians. Fuses are replaced only by electricians, except where a fuse is moved from one cut-out to another. About 600 fuse links are used at switchboards. There are 7000 cartridge fuses used for light-

ing circuits. A few cartridge fuses are improperly refilled. Some link fuses are used for heaters. Some question has arisen in the case of the approved fuses as to whether complete inclosure should not require a separate rating. Cartridge fuses have been replaced for this reason in some heater circuits, as they prefer screw contacts. They find the indicator on approved cartridge fuses unreliable. The refilling cost is negligible, as the regular fuse wire is used and holes are drilled in the cartridge to receive the fuse element. They are perfectly satisfactory. Manufacturers' refills are too expensive. These refilled fuses blow under rating, and are apparently safe on short circuit. About 3000 fuse replacements are made annually. They dislike the Economy fuse, as they anticipate that these fuses are too easily wrongly refilled and they are not approved. Upon inspection of a number of boxes non refilled approved fuses could be detected.

The cost of fuses is considerable, but the use of open links might burn men in handling or replacing them. They find it much harder to replace links, and short circuits will often occur.

10. A large department store in New York City employs four electricians. The fuses are replaced only by electricians; 2100 approved cartridge fuses are in service. They find that the indicators of the approved fuses are generally reliable. There are 100 fuse replacements annually. They do not use Economy fuses, as they prefer to have the manufacturer responsible for the fuse. Fuse expense is not regarded as serious. Careful inspections are made.

11. A manufacturing company in New Haven, Conn., employs two electricians, who replace all fuses. They have 110 cartridge fuses in service, of which eight are Economy. Forty link fuses are used in cabinets. Their experience with new Economy fuses has indicated that trouble comes from loose contact by insufficient tightening of fuse parts. There are two such cases out of eight fuses used. Expense is the only difficulty with the approved type of fuse. About 50 fuses are replaced annually, mostly of the 30-ampere size on motor circuits. They prefer the Economy fuse, because of low maintenance cost, and do not use more because they had a large stock of approved fuses on hand.

12. A tool manufacturing company in New Haven, Conn., employs one electrician. Fuses are replaced by the electrician, and are refilled at the stock room only. One hundred and ten cartridge fuses are in service, of which 20 are of the Economy make. A few of the Economy fuses were improperly refilled. They have had experience with old and new type of Economy fuses. No troubles have developed in the new type. In the old type the loose contact caused the fiber threads to char and made replacements impossible. This resulted from change in temperature and humidity and made the cost large. They consider this would also affect any other solderless contact. They find the indicator of new approved fuses to be unreliable, but have had no other trouble with them. Refilled Economy fuses are found to be properly rated, except when some have been refilled with fuse wire when the elements were not in stock. About 50 cartridge fuses are replaced annually, mostly of the 60-ampere size. They do not prefer the Economy fuse unless the new type performs better than the old. They found the Economy fuses to be less reliable because of loose contact, especially after refilling. They may save $15 annually at an initial cost of $50 in fuses on the motor circuits.

13. A manufacturing company in New Haven, Conn., employs three electricians who replace all fuses except when the engineer or a few of the foremen replace 10-ampere lighting fuses. About 460 cartridge fuses are in use, a few of which are improperly refilled. They consider the new approved fuses to have unreliable indicators, but to be otherwise satisfactory. Refilled approved fuses are apparently satisfactory. They refill the small cartridges in the plug type of fuse with the proper size of fuse wire and consider them to be satisfactory. Ten cartridge fuses and 50 plug fuses are replaced annually. They do not prefer the Economy fuse as it does not

pay to bother with refilling when so few are blown, and consider it much better to get a thoroughly reliable fuse manufactured in a good shop. The purchasing agent bought a lot of Economy fuses, but the electrician does not wish to bother with them. Fuse trouble is no problem where the plant is well maintained and circuits properly designed. All fuses are placed in cabinets, except some on the ceiling. Some annoyance during installation by blowing fuses led them to purchase a large number of Economy fuses, some of which have been used during that period, with a very few subsequently, to replace blown ones. At their rate of blowing it would take about 10 years for the Economy fuses to be a real economy, if the cost is twice as much as nonrefillable fuses. They had undoubtedly not figured very closely when they first began to purchase.

14. A business house in New Haven, Conn., employs one electrician, who replaces all fuses. He sometimes replaces fuses at the cut-out. Sixty cartridge fuses are in use, of which 20 are of the Economy manufacture. They have had experience only with the old-style Economy fuses. Their trouble, which they consider their own fault, has been due to loose contacts. They consider that some of the new approved cartridge fuses have loose ends, and they find that hands have been cut by the indicators. The indicators are considered unreliable. Refilled Economy fuses are considered to be properly rated. Six fuse replacements occur annually. They prefer to use the Economy fuse and in time will have a large stock of them, but do not wish to throw the other fuses away until they blow.

15. A manufacturing company in New Haven, Conn., employs 101 electricians, who replace all fuses. They refill fuses at the stock room only. Approximately 6050 cartridge fuses are in use, of which 400 10-ampere fuses are of the Economy make. Their experience with new Economy fuses has resulted in one case of a cap blowing off on short circuit and one case of puncturing under the ferrule. No trouble has been experienced with loose contacts or burning. Some knife-blade types of standard new fuses have burned and charred and one has blown the filling out at one end. They do not find it feasible to send fuses to be refilled by the manufacturer. The cost is one-third that of new fuses and their rating is bad. One hundred new fuses burst, the filling of which looked like plaster of Paris. They did not consider these to be safe on short circuit. Consider refilled Economy fuses to be properly rated in the size they use and safe on short circuit. One cartridge is good for 50 renewals. About 2500 standard fuses and 20 000 Economy elements are used annually. They do not prefer the Economy fuse and do not use more because of accidental mixture of sizes of elements and consequent overfusing. They use but one size of element in all the Economy fuses. Small circuit breakers have been tried, but are hard to make work well, and the Economy fuse is used purely on account of expense, not of convenience.

The company believes circuit breakers should be used where fuses blow frequently on variable duty machines. Otherwise they prefer fuses as requiring less attention and having a small cost. All fuses are in cabinets. Daily inspections are made in their factory by three special fire inspectors, in addition to inspection of electricians. The extra insurance is considered to justify having fuses inclosed in cartridges and cabinets as well.

16. A dry-goods company in Bridgeport, Conn., employs two electricians, who replace all fuses. Fuses are sometimes refilled at the cut-out. Three hundred and forty cartridge fuses are in service, of which six are of the Economy make. They have had no trouble with new Economy fuses. Refilled Economy fuses are apparently properly rated and safe on short circuit; 100 fuse replacements are made annually. They prefer the Economy fuse and will use more, as other cartridge fuses blow.

It appears that it would take five or six years at current differences in prices to make Economy fuses pay in this installation, but it does not seem to have been considered before by the engineer. They have never considered the use of circuit breakers in place of links on the switchboard. They have had trouble from heating of joints

between the fuse metal and copper tips, due to expansion and contraction. They now have some large unnotched flat fuse strips directly held under terminals.

17. A factory in Bridgeport, Conn., employs three electricians, who replace all fuses. They use 634 cartridge fuses. They consider the indicators on standard new cartridge fuses to be unreliable. Have tried some refilled approved-type fuses, but found them very unsatisfactory. They are considering having fuses refilled by the manufacturer. Their refilled fuses have cost 20 per cent less than new ones, but blew under rating. They do not consider refilled Economy fuses to be properly rated. One hundred cartridge fuses are replaced annually. They do not prefer the Economy fuse, but are not particularly interested, as their fuse troubles are not serious. They do not want refillable fuses everywhere, as they are too easily refilled improperly. They might use them if the fuses were approved. It is easy to detect an abuse of approved fuses, but not easy to find wrong refilling of the Economy fuse.

This firm has never used any Economy fuses. All fuses are in locked cabinets. Fused rosettes are used to avoid a large number of lights being out at the same time and interfering with the work.

18. A manufacturing company in Bridgeport, Conn., employs one electrician, who replaces all fuses. About 370 cartridge fuses are in service, of which 50 are of the Economy make. No experience has been had with the new type of Economy fuse. They have found the old style to blow owing to poor contact. They consider refilled Economy fuses to be properly rated; 50 fuse replacements are made annually. Economy fuses are preferred because they can be stocked more easily and the renewal elements can be carried in the pocket. They think there might be a chance for error with different size elements, but would use more if they were approved. All fuse cut-outs are placed in cabinets.

19. A manufacturing company in Bridgeport, Conn., employs three electricians, who replace all fuses, some of which are refilled at the cut-out. About 312 cartridge fuses are in service, of which 100 are of the Economy make. They have used only the new type of Economy fuse and find that losses of small parts cause a loss of the casings. The elements break at the bend. They have refilled approved fuses by drilling through the cap, inserting a wire and replacing the powder. They were not sure of the rating of such fuses, but they were apparently safe on short circuits. Refilled Economy fuses are probably properly rated and safe on short circuit. One hundred cartridge fuses are refilled annually. They prefer to use Economy fuses because they can keep a large stock of elements on hand. There is no reason, therefore, for having a circuit without a fuse. Their experience has been only with small sizes. They would rather take the extra time required to replace the Economy fuses than to have the men look for the cause of the trouble.

Circuit breakers are in practically every motor circuit, including the very small ones. They believe that breakers are the only proper protection for motors. All fuse cut-outs are in cabinets.

20. An iron works in Bridgeport, Conn., employs two electricians, who replace all fuses. Such fuses are refilled only at the stock room. One hundred and ten cartridge fuses are in service, of which four are of the Economy make. They have had no trouble in the use of the new Economy fuses or in the new approved types. Apparently the refilled Economy fuses are properly rated and safe on short circuits. Fifty replacements occur annually. They prefer the Economy fuses for motor circuits, except that where practicable circuit breakers are always preferred to everything else. They expect to use more as time goes on.

They have only one small size of Economy fuse, and their experience has been only that of three or four months, so they do not speak with confidence. The fact that a large stock of renewals can be kept on hand makes them think that replacements would be quicker and surer. However, if foremen refill they believe the waste of time would be very expensive and the chance for wrong refilling very great.

21. A manufacturing company in Bridgeport, Conn., employs 22 electricians. who replace all fuses except where workmen surreptitiously change fuses from one cut-out to another. Fuses are refilled only at the stock room. Several thousand cartridge fuses are in use, of which 75 are of the Economy make. A few of the latter have been improperly refilled. They have found both the old and new style Economy fuses to blow under load, but no other trouble has been experienced with them. They consider new approved fuses to have unreliable indicators. They refilled approved fuses up to 31 amperes, but the Chase-Shawmut fuse requires so much refilling that they gave up the idea. They do not consider fuses refilled at the factory satisfactory, as such fuses are more liable to be improperly refilled. They take more chances of getting improper re-fusing than by doing the refilling themselves. Refilled fuses are considered to be properly rated and safe on short circuit both of the approved and Economy types. About 250 fuses are replaced annually, including the Economy make. They prefer the Economy fuses for large circuits. Small fuses would not pay because of the infrequent blowing and the very little cost of approved fuses. They will probably use more Economy fuses.

This firm has done considerable refilling of their own fuses, but after some conversation and the showing of some samples we had collected they seemed not very proud of their present practice. They could not find any of their own refilled fuses.

It is noteworthy that of 23 large users of fuses (totaling over 45 000 fuses in service and about 8000 replacements annually, exclusive of the peculiar single case where 20 000 annually are blown in one room), chosen from a list of reported users of Economy fuses, 7 reported no use of such fuses, 5 reported experience only with old types, and 2 more have practically none with the new type. Twelve do not prefer Economy fuses to nonrefillable, and 9 give reasons for disliking the former. Of those 5 having experience only with old types of Economy fuses 2 dislike this fuse. Most of the favorable experience is reported from those companies having tried the new kind, but these report a comparatively short experience.

On the whole the advantage in the use of Economy fuses has apparently been emphasized by users less than would be expected of a thoroughly satisfactory device, and the new type has not yet been in use long enough or in large enough numbers to entirely demonstrate its advantages.

INSPECTIONS IN PHILADELPHIA, PA.

In order to investigate the condition of fuses at Philadelphia in the occupancies commonly known as "sweatshops," the writer [6] spent two days (June 28 and 29, 1915) in that city visiting these risks.

I inspected about 22 occupancies in 13 buildings on the first day, at separate selected points in that district. I found the conditions so bad that I arranged to take one city block and visit as many of the occupancies as I could in the time allotted. The second day I visited 41 occupancies in 23 buildings.

I inspected altogether 379 cartridge fuses and at least 75 plug fuses and found only one Economy fuse in service. Of these, 17 cartridge fuses had been bridged with copper, steel, and other wires of high melting point and large sizes of fuse wires. I brought back 36 samples taken from 23 separate cut-outs.

The conditions of overfusing and bridging of fuses are very bad and present serious hazards in almost every place visited. It is certainly time that something should be done to help these conditions. There is a great need of making a decided improvement in these occupancies.

[6] F. W. Glading, an associate electrical engineer of this Bureau.

I find that the inspectors expect a large amount of overfusing, and they blame the present designs of fuses for the conditions. Many 30-ampere fuses were in use where 10-ampere fuses would be sufficient. This may be due to the 30-ampere and the 10-ampere cartridge fuse cases being made to the same dimensions. Many of these 30-ampere fuses as well as the knife-blade type show much overheating, resulting in a rapid deterioration of the contacts. There were a number of large blown fuses the fusing of which could hardly be accounted for except by overheating and consequent drawing of temper of the fuse clips. I saw many of the larger fuses in use where the heating was very considerable.

INSPECTIONS MADE JUNE 28, 1915

1. Clothing manufacturer: Eight cartridge fuses were inspected. Two 25-ampere fuses were used on a 3-horsepower, 220-volt direct-current motor.

2. Eight plug fuses were inspected. There was apparently no abuse of fuses.

3. Hosiery manufacturer: Twelve inclosed fuses were inspected in basement. Removed one 50-ampere (D. & W.) and one 60-ampere (unknown make) cartridge fuses as samples from the customer's service. Each of these was bridged in the cut-out with a piece of fuse wire. The coil of fuse wire shown had been left probably for future use. The owner replaced these with new fuses, which he purchased at the time at the request of the Underwriters' inspector. Removed two cartridge fuses (unknown capacity) and probably blown in cut-outs controlling a 5-horsepower, 220-volt elevator motor, replacing them with two 30-ampere good fuses. The fuses removed were bridged in the cut-out clips with copper wire. One fuse shows burning and fusing of the copper wire. The clips were badly burned and the contact with the ferrules was very poor, with considerable heating. The switch and cut-out was placed in a horizontal position mounted on the ceiling. The remaining eight cartridge fuses were apparently all right.

4. Eight cartridge fuses were inspected, which were apparently all right.

5. Eight cartridge fuses were inspected. The exhibit was taken from a cut-out on a 1-horsepower, 220-volt sewing-machine motor. Originally it was a 6-ampere "Arkless fuse" N. E. C. S. made by the Detroit Fuse Manufacturing Co., but it had been refilled with copper wire. This was replaced with a 10-ampere fuse. The other seven fuses were apparently all right.

6. Twelve cartridge fuses were inspected in the basement. One switch in this basement showed evidences of burning. The fuses were apparently all right.

7. Two cartridge fuses were inspected; apparently all right. Inspector remarked that on previous inspection a nail was driven through one of the fuses on the elevator-drive circuit.

8. Four cartridge fuses inspected were apparently all right. In a previous inspection a 30-ampere switch and cut-out had been ordered removed, so we found a new switch and cut-out. The clips on the former cut-out were said to have been destroyed by the fuse wire being loosely laid in same; the bad contact had caused severe arcing and destroyed them.

9. Sign manufacturer: Twelve cartridge fuses were inspected. The cut-out for a 3-horsepower, 220-volt motor for running the house water pump had one-fourth of the clips on one side burned off. The other side had a copper wire shunted around the fuse, so providing single fuse protection through a set of bad clips.

10. Six cartridge fuses were inspected. Two fuses were removed and a No. 14 B. & S. gauge rubber insulated copper wire, with insulation removed from two ends, making contact at each end clip, was used on one side. The other side had numerous strands of fine steel wire (about No. 36 gauge), making up to about a No. 12 B. & S. gauge. This was not removed. The slate base was pitted and discolored from past blowing. A piece of fuse wire was taken from the bottom of the cabinet, showing another possibility of abuse.

11. Two cartridge fuses were inspected. Two 15-ampere N. E. C. S. Johns-Pratt fuses were removed for exhibit and replaced with two 10-ampere fuses. Both the 15-ampere fuses had apparently blown and were respectively bridged with 35 and 40 ampere G. E. company copper-tipped link fuses. We also noted in this place No. 14 B. & S. gauge BX cable having 15 amperes as the allowable safe carrying capacity.

12. Basement, clothing manufacturer: Four cartridge fuses were inspected in basement; mostly Edison plug fuses are used for the five clothing manufacturers who occupy this building. The total number of fuses inspected was not counted. We saw one 30-ampere, 110-volt switch on the 220-volt circuit, which has been condemned by inspection service.

13. Twenty-four cartridge fuses were inspected in the basement. These were on the switchboard of a private 220-volt plant. In one instance a 60-ampere (Shawmut N. E. C. S.) fuse had been refilled with a No. 6 B. & S. gauge copper wire, no filler being used. The solder had been melted at one end, making poor contact. A 50-ampere fuse (type A clips) was used in clip contacts. The type A clips, whose diameter was larger than the fuse, were bent around it and there was barely a line contact on one side.

One clip on the main switchboard had evidently been damaged by abuse through bridging with wire in the past, as a small piece of fuse wire was found around the upper clip, one end having been fused off. One clip also had one-fourth of its metal fused off.

14. Two cartridge fuses showed indications of improvised fusing by the burns on the slate base. Other fuses were apparently all right. They had in service on this floor two Economy fuses, with filler. These looked all right.

15. Two 30-ampere inclosed fuses in basement were inspected. They were somewhat corroded from dampness, but otherwise apparently all right.

16. Two cartridge plug fuses were inspected. A one-half horsepower rheostat on one-fourth horsepower, 220-volt motor was fused with 20 and 25 ampere fuses. Actual full load current of motor about 1 ampere.

17. Two cartridge fuses were inspected. One 6-ampere Union N. E. C. S. cartridge fuse was blown and fused with piece of fuse wire placed alongside it. The other fuse was blown and was also bridged with about a No. 30 B. & S. steel wire. Capacity of this fuse was not marked.

18. Electrical contractor, dealer in second-hand motors and sewing machines. This man does the work at occupancy cited No. 16. Five cartridge fuses were inspected. They had an emery wheel on the first floor driven with a one-half horsepower motor. It was fused with one 30-ampere fuse of unknown make, and one 10-ampere Union N. E. C. S. fuse, both blown. One was bridged with copper and the other with fuse wire. In the basement we found on the service a 25-ampere Johns-Pratt N. E. C. S. blown fuse bridged with a piece of fuse wire.

19. Knitting company: Ten cartridge fuses were inspected. We did not find any overfusing, but did find much heating at clip contacts. This might have been due to imperfect contact caused by the large amount of cotton flying around from the knitting machines.

20. Twelve cartridge fuses inspected in basement were apparently all right.

21. Coat and apron manufacturing company: Four cartridge fuses were inspected. One branch circuit was fused with 15-ampere cartridge plug fuses. One was bridged with copper wire, and signs of burning were noted on shell of plug and at contacts. Further abuse was seen in the loose fuse wire in the cases. The threaded portion of one plug case showed considerable thread burned away, due to bad contact.

22. Number of fuses was not noted. Edison plug fuses used were apparently all right.

INSPECTIONS MADE JUNE 29, 1915, MOSTLY IN ONE CITY BLOCK.

23. Forty fuses, plug type, were inspected. Five cartridge fuses inspected were apparently all right.

24. Eight cartridge fuses inspected were apparently all right.

25. Two cartridge fuses were inspected. We found one 30-ampere fuse on one side of a 2 horsepower motor using No. 14 wire. There was a 6-ampere fuse on the other side.

A second circuit had a 30-ampere fuse and the case was considerably marred, apparently due to tampering with it. Small particles of solder had extended beyond the end of the ferrule.

We took as samples two Shawmut fuses, one 6-ampere and one 25-ampere, from cartridge plug fuse cases, as the filling and solder looked suspicious. These were found to be refilled with lead fuse wire. The branch on which these were used had only one lamp.

26. Two 15-ampere cartridge fuses on a 3-horsepower, 220-volt, motor were apparently all right.

27. Optical company: Twelve Edison plug fuses in a cabinet were inspected and were apparently all right.

28. Electrical contractor: Three cartridge fuses were inspected in basement. One 15-ampere cartridge fuse in neutral and two 10-ampere on outside, apparently all right.

29. Shoe manufacturing company: Four cartridge fuses inspected were apparently all right.

30. Two plug fuses were inspected and found apparently all right.

31. Express company: Six cartridge fuses were inspected. Four 10-ampere fuses were apparently all right. One 20-ampere cartridge fuse with type A clip was blown, and a copper tip G. E. link fuse placed under the binding post.

32. Two Edison plug fuses on small motor were apparently all right.

33. Raincoat manufacturing company: Twelve cartridge fuses were inspected. Four fuses were apparently all right. Two of these four are 10-ampere capacity on 1-horsepower motor. One had four strands and some extra pieces of No. 36 B. & S. gauge copper wire wound around the clip. The other fuse was apparently all right.

34. Six cartridge fuses were inspected. One 30-ampere and one 15-ampere fuse on 3 horsepower, 220-volt, motor were apparently all right. Of two Edison plug fuses used, one had the cap off. Two main fuses on this floor were apparently all right. In the basement on this consumer's circuits, there were two cartridge fuses. One 30-ampere N. E. C. S. Johns-Pratt fuse was burned out but supplemented with G. E. copper tip 35-ampere link fuse.

35. Two cartridge fuses were inspected. Breaker and fuses on a Morse-Williams elevator. On the meter board were two 35-ampere fuses, and three open-link fuses in an asbestos wood cabinet. Asbestos was removed from the door. The link fuses were mounted on porcelain base not at present approved. This was doubtless a very old installation.

36. Four cartridge fuses were inspected. Five Edison plug fuses in basement were apparently all right. Two 20-ampere cartridge fuses on No. 14 wire (5 amperes overfused).

37. Four cartridge fuses were inspected, also two plug fuses, all apparently all right.

38. Skirt manufacturing company: Eight cartridge fuses inspected. One horsepower motor supplied with 10-ampere United N. E. C. S. fuses (United Electrical Co., Brooklyn). One was bridged with a steel nail.

Four cartridge plug fuses with fine copper wire around each. Two were 10-ampere Johns-Pratt. Two others were Union fuses, respectively 5 and 10 amperes. Two of these were replaced. One 30-ampere fuse in the basement was found bridged.

39. Four cartridge fuses were inspected. Two 30-ampere cartridge fuses on a 3-horsepower motor No. 12 wire were quite hot and could hardly be handled. The contact on the clips was poor.

They had two cartridge plug fuses with copper wires bridged across them. One of the screw bases is badly burned.

40. Five Edison plug fuses used only for lighting were found apparently all right.

41. No electrical equipment.

42. No electrical equipment.

43. No electrical equipment.

44. Eight cartridge fuses were inspected. This is a comparatively new six-story building in which the original equipment was apparently up to date and carefully made. They use flush panels and concealed wiring in concrete. There were indications of heating on two 30-ampere fuses which were mounted in an iron box, and on inspection the fuse terminals were found to make bad contact.

A 12-circuit standard lighting panel board with 2-wire branches from 3-wire bus bars was interesting. Ten of the circuits were in use, with two spare circuits. Six of the plugs had been blown and fuse wire placed under each. Two others were without plugs, but terminals were bridged with fuse wire in bunches. All circuits from this board were used for lighting.

In this panel board, circuit No. 1 contained a 6 and a 30 ampere fuse. Circuits No. 2 contained two 30-ampere plugs apparently all right. Circuit No. 3 had fuse wire in back of the blown 6-ampere fuses. Circuit No. 4 had a 30-ampere fuse, and a 10-ampere fuse blown, the latter with fuse wire under plug. Circuit No. 5 had a 30 and a 10-ampere fuse. The 30-ampere fuse had blown and fuse wire was placed under it. Circuit No. 6 had one 10-ampere fuse which was all right; the other was bridged with fuse wire. Circuit No. 7 had no plugs in receptacles, but only coils of fuse wire. Circuit No. 8 had a 6-ampere fuse blown, with fuse wire in receptacle and a cartridge plug case with a 10-ampere cartridge fuse. Circuit No. 9 was not fused. Circuit No. 10 had one 30-ampere fuse. Circuits Nos. 11 and 12 were spare circuits.

On this same floor a 3¾-horsepower motor, 220 volts, was fused with two 30-ampere fuses. The receptacles were burned and pitted, probably due to fuse abuse in the past. The contacts were bad and the amount of metal was reduced.

Another 3¾-horsepower motor had two 30-ampere cartridge fuses which were apparently all right, but with indications of burns on contacts.

For the two 3¾-horsepower motors No. 12 B. & S. mains were used. Two 30-ampere cartridge fuses were next inspected and found all right, except for heating at contacts.

A 12-circuit flush panel board was located in the rear on this floor, but only one circuit was fused. We took out the D. & W. cartridge fuse plugs and fuses which were refilled with fuse wire.

In this plant they have provided a fire drill, with the head of the firm as fire marshal. Apparently a wise precaution in view of the fire practice observed.

45. Three 15-ampere cartridge fuses on mains and 6-ampere fuses on each branch circuit of a 12-circuit panel. Fuses were apparently all right.

46. Fifty cartridge fuses were inspected. One circuit contained two 35-ampere fuses and one of 40-amperes. They looked suspicious, as though they might be filled with a copper wire. In another circuit a cartridge fuse was bridged with a copper wire soldered to the two ferrules and taped. A third circuit had 60-ampere fuses which were bridged over the clips with two strands of No. 16 B. & S. copper wire on one fuse with the neutral the same. The other fuse had three strands of No. 16 steel wire. A fourth circuit had a broad strip of copper exposed on the end of 50-ampere fuses, but this was probably due to poor factory assembly.

47. The service is not used in this building.

48. Manufacturers of hosiery, underwear, and notions: Four cartridge fuses were inspected. In the circuits in the basement of the adjoining property which feed this occupancy we found No. 12 B. & S. wire used with two 25-ampere fuses. One of these was a Johns-Pratt N. E. C. S. fuse bridged with a 40-ampere G. E. copper tip link. This was on a load of a 2-horsepower and a one-fourth horsepower motor. We replaced this. We found two more 25-ampere fuses on No. 10 B. & S. wire, but they were apparently all right, except too high for the load.

49. Nine cartridge fuses were inspected. We removed one 25-ampere Johns-Pratt N. E. C. S. fuse bridged with G. E. 15-ampere copper tip link, and one 10-ampere "United" N. E. C. S. fuse, bridged with 30-ampere G. E. copper tip link, and put in place two fuses. This circuit had No. 14 wire. The other circuits were apparently all right, except that one plug fuse was without a cap.

50. Plug fuses were apparently all right.

51. Raincoat company: Four Edison plug fuses were apparently all right.

52. Two cartridge fuses were inspected. Two 15-ampere cartridge fuses on one motor running sewing machine. These were apparently all right.

53. There was nothing of interest.

54. This was a moving-picture theater which we did not inspect.

55. This was unoccupied.

56. Four cartridge and 13 Edison plug fuses, all of which were apparently all right.

57. Twelve cartridge fuses inspected in basement were apparently all right. There were also a large number of plug fuses. Six of the cartridge fuses were in a service vault under the pavement. An Otis elevator motor in a separate room in the basement had two 60-ampere fuses, which were apparently all right. In this room there were two apparently good 10-ampere fuses for elevator lighting. In another room in the basement two 30-ampere fuses were used on a 1-horsepower motor on No. 14 B. & S. wire. This motor was used for pumping water.

58. Six cartridge fuses were inspected. On the sixth floor of this building we found two 25-ampere cartridge fuses on a 3-horsepower motor. Except for heating at contacts they appeared all right. Another 3-horsepower motor had two 30-ampere fuses apparently all right. On the ceiling branch for this motor there was a 25 and a 20 ampere fuse, apparently all right. Two 25-ampere cartridge fuses on another circuit were apparently all right, except that the contacts were very hot.

59. Four cartridge fuses were inspected. We found two 30-ampere fuses on No. 14 B. & S. wire on a 2-horsepower motor, and there was some heating at contacts. On the meter board there were two 30-ampere cartridge fuses, apparently all right, on the same motor circuit.

60. Eight cartridge fuses were inspected. We found two 60-ampere fuses apparently all right. Also found two 15-ampere Edison plug fuses on a 3-horsepower motor apparently all right. Two 15-ampere cartridge fuses on a one-half horsepower pump motor were apparently all right. Two 30-ampere fuses on No. 12 B. & S. wire were used on the meter board. A coil of fuse wire was found under one fuse and the other base showed excessive burning and pitting.

61. Two Edison plug 60-ampere fuses were apparently all right. Fuses were used on a 3¼-horsepower Diehl motor. There were no occupancies on the second and first floors and basement.

62. Service was cut off in the basement.

63. Six cartridge fuses of 6 and 10 ampere capacities were apparently all right. We saw five Edison plug fuses with the mica windows broken. Fuses were otherwise all right.

The sixty-third occupancy was the last place inspected.

SUMMARY

Buildings visited	36
Occupancies visited	63
Cartridge fuses inspected	379
Occupancies from which samples were taken	19
Samples of apparently defective fuses	36
Cut-outs from which samples were taken	23
Fuses where overfusing was noted on both sides of circuits	52
Fuses where overfusing was noted on one side of circuit only	17
Cases where copper wires were used directly in place of fuses	2
Cases of bridging fuses with fuse wire, copper wire, or other wire, but which were not taken as samples	17

There may have been a large number of cases of overfusing which were not noticed, as for want of time we only checked up suspicious-looking cases.

INSPECTIONS [7] IN PHILADELPHIA, PA., AND BALTIMORE, MD.

BALTIMORE

These inspections were made on July 13 and 14, 1915.

1. Department store: Inspected two buildings. Total number of fuses in one building was about 350; 50 used in other building. Inspected most of these. With two assistants, chief engineer makes replacements. Many of the original D. & W. fuses placed seven years ago are still in use. He now uses mostly Johns-Pratt fuses, although he has about 150 Edison plug fuses in cut-outs on ceilings. Ten Economy fuses of the old type with filler were bought a year ago. Does not want any more. I found one Economy fuse very hot. On removing it found both ferrules were partly unscrewed, so that end contacts were bad. He says he has had this trouble before, explaining it as being caused by difference of expansion. An approved 15-ampere Connecticut Electric Manufacturing Co. fuse had been refilled. Saw several others which looked as though they had been tampered with.

2. Large electrical concern: Inspected fuses in testing department. Found a 200-ampere "Union" knife-blade fuse (apparently unblown) but reinforced with a bridge of approximately No. 16 B. & S. wire (looked like tinned copper). This was in one leg of a three-wire circuit. The other two were not bridged. The explanation was that this side persisted in blowing until this means of stopping was resorted to. They refill all sizes of approved fuses up to 400 amperes. They take off the ends and wrap copper wire or aluminum fuse strips around blades on the inside, and their only complaint was that with the latter they could not readily solder. This company uses large number of fuses. They purchased at one time 10 Economy fuses of the 100-ampere size, and do not recommend their use. They say that in the hands of a man who will be careful these may be all right, but they especially do not recommend them for use on lighting circuits on account of the temptation to place large sizes in the holder, as, for instance, a 30-ampere fuse in a 10-ampere case, etc. My visit to them was in the testing department, where the unusual conditions would doubtless lead to the overfusing and conditions above noted.

3. Electrical contractor: The president made the statement as a supply merchant that all fuse companies will refill fuses and that it is only necessary to send the fuses to them and they will be glad to have the business. He says his company does not refill fuses, except that they sell Economy fuses and make their refills.

4. Large hotel: Met the engineer on watch and the electrician. They have approximately 1000 (estimated) fuses in use of the nonrefillable type, and advised me

[7] By F. W. Glading, an associate electrical engineer of this Bureau.

that they refill in their shop 75 per cent of all the fuses they use. They do this by using ordinary fuse wire purchased from the Chicago Fuse Wire Co. In the panel board in the kitchen with 24-hour service I found every fuse was hotter than would normally be expected, apparently due to overload. Push-button flush switches in the panel must have had very considerable overheating as the whole face of the flush metal panel construction was as hot as could be borne by the hand. In a panel for the banquet room I found two 250-watt and two 100-watt lamps installed on a refilled 10-ampere fuse. They also use 48 to 55 eight-candlepower carbon lamps on special decorative constructions. They use copper link fuses on main switchboard.

5. Large electrical concern: Did not inspect any fuses, but superintendent does not believe that the Economy fuse is a very good fuse for his purpose, on account of the chance of improper refilling with the wrong size element.

6. Inspected two plants. On May 7, 1913, they purchased 25 Economy fuses. Met machinist who handles their fuses. In one pumping station there are approximately 450 fuses. Number of motor circuits about 18. States that the amount of time spent for refilling about 150 fuses per year is represented by about two days' work at a cost of about $5. They use Chicago fuse wire for refilling both Economy and nonrefillable fuses. I secured a number of 10-ampere and 50-ampere refilled fuses of the nonrefillable type, together with samples of 10-ampere and 20-ampere fuse wire which they use. For making up a 60-ampere fuse they twist together three 20-ampere fuse wires. An Economy fuse refilled for my benefit is also included. This is refilled with the 10-ampere fuse wire.

7. Extensive user of Economy fuses: Manager stated that he was well pleased with them and that they had no difficulty in getting their men to refill them properly.

8. Large lime manufactory: They have several plants and use both Economy and nonrefillable fuses. They are well pleased with Economy fuses and have had no trouble.

9. Large office building: Use Economy fuses almost entirely. The first fuse shown me was one which had been blown. On dismantling it I took out two 10-ampere strips from a fuse marked "10 amperes" on the case. Looked over the building, but did not detect any other specially bad conditions. Did not secure any samples.

10. Dairy: Secured an Economy fuse marked "20 amperes" and painted with red ink to indicate that it has been refilled with a 30-ampere size. This is their regular practice. They use a number of 600-ampere size Economy fuses, the refilling of which is accomplished by using four 150-ampere links in multiple. The engineer says that five or six could readily be placed in the cases, which disassembling shows. He has used 287 renewals of this size in about 18 months and has 100 in stock. He formerly placed a small amount of asbestos magnesia 85 per cent pipe covering in the case to protect the shell. At the suggestion of the salesman he has discontinued the use of the filler. He has used about 50 to 60 Economy fuses and likes them because they do not spit fire as do the indicators on other fuses. I saw one Economy fuse burnt at one end where it was not tightly put together. He has trouble with his ice-cream man, who also does refilling as the latter strips the threads on the old type of Economy fuse.

11. Machine shop: Uses Economy fuses and likes them. Apparently does not improperly refill with the Economy elements. I saw a 200-ampere D. & W. knife-blade fuse bridged under the screw heads with copper wire. These people like the Economy fuse on account of the economy of refilling, but have had trouble with the ferrules becoming loose.

PHILADELPHIA

These inspections were made on July 15 to 17, inclusive, 1915:

12. Printery: Has about 50 motors; uses about 350 fuses. Bought one package of 30-ampere Economy fuses, but did not like them as he said they were not economical.

They cost more, due to the burning off of the ends. Apparently the ferrules loosen up, causing bad contact. In this plant each foreman puts in his own fuses, but one man does all refilling.

The assistant engineer was very sure that I would not find any examples of refilling of nonrefillable fuses, but I found two examples after having looked over almost all the fuses in circuit. The assistant engineer could not understand why this was done, as he keeps a good stock of fuses, and it was only necessary for the press workman to ask his foreman for a fuse to obtain it.

13. Printery: An Arkless fuse had been poorly soldered. They use the Union fuse and also the Economy. Their experience has been good with the Economy, although the elements open only at one notch. They know that an Economy fuse is gone only when a mechanic complains that his machine does not operate. They have used them only three months, but expect to adopt them for general use.

14. Large office building: Met the acting chief engineer. They have been using Economy fuses for the past two years and now use them almost exclusively. An inspection of several of their panel boards and other places showed no apparent abuse of fuses. They like the Economy fuse very much and find it quite economical.

15. Stationers' supply house: Two standard fuses were refilled with ordinary fuse wire. These are not soldered. The chief engineer just hammers the ends to secure the contact. He uses nonrefillable fuses mostly, occasionally using an Economy fuse. He has about 250 fuses installed in the warehouse of which about 15 or 20 are Economies. He refills all fuses of all types.

16. Factory: They use a large number of Economy fuses and like them very well, although they have had several cases of the ferrules becoming loose.

17. Hotel: Use about 650 fuses, mostly of the 6-ampere size. They have used about 100 Economy fuses and also 10 of the multirefillable type. I saw no evidences of fuse bridging. Most of the branch lighting circuits were equipped with 6-ampere fuses. They have soldered clips on ordinary "Noark" ferrule type fuses to make them fit in a type A fuse block. A 15-ampere D. & W. fuse had the type A clips purposely broken off to use this fuse in a ferrule type holder.

18. Large publishing company: This represents an up-to-date printing establishment with a splendid personnel. The building is of high-grade, fire-resistive construction. Economy fuses are used almost exclusively. The electrical equipment includes some nonrefillable fuses (usually furnished with electrically driven presses by the contractors). The specification of Economy fuses on a large new addition to the building makes them a very large user of this type of fuse. While the chief electrician believes the Economy fuse is very good for many purposes, he has had difficulties with it in this installation. Workmen will persist in stealing a fuse from another man's machine in order to keep their own operating, throwing away the Economy fuse which had been blown. A rather large number of fuses lost in this way has made the Economy proposition rather uneconomical. He has tried several makes of refillable fuses, including the Multirefillable fuse. One sample of the latter had been replaced after fusing because it had a conducting film on the inside of the fiber case. He has not tested this. As the Economy fuse is used without a filler his electricians have renewed other makes of refillable fuses without a filler. The use of other types of refillable fuses was due to a desire to obtain a refillable type cheaper than the Economy. He mentioned the Great Western refillable fuse but did not have samples.

19. Large department store: I met the assistant chief electrician. It was reported that the chief electrician will gradually replace all other types of fuses with the Economy fuse, as he believes it greatly to their advantage to use them. The assistant engineer, however, advised me that they did not like the Economy fuse, and that they were not now purchasing any of that type, all fuses coming in being of an approved nonrefillable make. His reason for not using the Economy fuse was that they have had so

much trouble with the blowing off of the ends and burning of the cases due to the bad contacts, and that the Economy fuse was not an economical fuse for them to use. I found two methods used by the D. & W. company which I understand have not been very long in use and were practiced up to a shipment as late as two weeks ago. On a 300-ampere, 250-volt D. & W. fuse the following label was pasted: "Return for reloading to D. & W. Fuse Co., Providence, R. I. Save your blown fuses." On a 75-ampere fuse of the same make the ordinary fuse label contained the words: "Return for reloading." I saw a 100-ampere D. & W. fuse which had been blown marked with the word "reloaded" across the label.

20. Large hotel: This hotel uses a large number of Economy fuses and is very much pleased with them on account of the cheapness of reloading. They have had no special trouble with them. They stated that they had about 100 in use, 25 of which were of the new type. The sizes used were 5, 15, and 30 amperes. I observed the use of a 30-ampere Economy fuse on a branch circuit which should have been fused not higher than 10 amperes. I obtained a Union 10-ampere fuse, the pins of which were partly removed from the ferrules and a copper wire wound around the pins; also a burnt-out Economy fuse which contained a piece of ordinary fuse wire as evidence of improper fusing. I also noted in several places, especially in circuits furnishing current to the banquet hall, the use of fuse wire to bridge burnt-out fuses.

21. Restaurant: These people use Economy fuses and like them very well. Since January of this year they have used 40 of them and report no trouble. In their equipment I found two 60-ampere approved fuses bridged with fuse wire around the ferrule terminals.

22. Printery: They use Economy fuses to some extent, having some in use as long as two years. Eventually they will entirely equip with them. They have about 350 fuses installed in the building with about 40 Economy fuses. They had no particular comments to make relative to the Economy fuse, except that of the ends coming loose to some extent.

23. Large hotel: Out of approximately 1500 fuses in the building about 750 are plug type and the other 750 are cartridge fuses, about 10 per cent of these latter being Economy fuses. They like the Economy fuse because it has a marking on the fuse element itself, but do not like it because men will turn the fuse clip around so that they can not see the marking. They have had no trouble and believe that Economy fuses are better than the old type of fuse, which can be bridged with ordinary copper or other form of bridge. I found that they used 3-ampere plug fuses for sleeping rooms. I saw no apparent tampering or bridging of fuses, but saw a sample fuse of refillable type with a chuck used for retaining fuse wire. This had no name on it.

24. Laundry company: This laundry has used 12 Economy fuses for the last three years and likes them so well that they expect to standardize on them and use nothing else in the future. I saw an Economy tube with the end burnt off. This they attributed to the fact that possibly the man had not used the asbestos tube over the renewal element. They use rather low-grade help for operating their engine and it is likely that this fuse was improperly refilled.

25. Express company: They have used a large number of Economy fuses, especially in the 100-ampere size, on their charging panels of storage battery trucks. They made the remarkable statement that the Economy fuses blew almost at the rating mark, whereas the refillable type blew at approximately 60 per cent of the rating. They complain that the threads on the fiber of the Economy fuse are too short. This has been remedied in their refills by placing an extra piece of metal between the fuse and the inside of the ferrule to make end contact secure.

I noted a large number of 100-ampere Economy fuses both on the switchboard and in reserve on which the contacts had not been screwed down to make proper contact. They like the new type of Economy fuse, except that they would prefer to have the fuse element covered with an asbestos shield or some protection which will in turn

protect the inside of the fiber against burning. They have refilled one case as often as four or five times.

26. Garage: They use fuses only on branch cut outs, and I saw evidence of overfusing by the use of 30-ampere fuses in some instances for lighting circuits. A few Economy fuses are used, but nothing special was noted.

27. Garage: Fuses are used here for the purpose of charging storage batteries for electric automobiles. They are mostly of the 60-ampere size. I obtained two blown Multirefillable fuses, one of which shows a hole of considerable size through which the filler had dropped, exposing the link. In this plant they also use Economy fuses and like them fairly well because they are somewhat cheaper after having been used a number of times. The use of the Multirefillable fuse indicates that they have been looking for a cheaper type of refillable fuse. I saw no evidence of improper assembly of Economy fuses in use.

SUMMARY

The risks visited on the trip were of an entirely different class from those given in my report of July 6. However, the general conclusion reached is one that probably would be verified by observation in almost any section of the United States, namely, that it seems to be human nature to bridge fuses under many conditions. This applies to both the refillable and nonrefillable types, but among the occupancies inspected the tendency to abuse the nonrefillable fuse was apparently the greater.

While most of this bridging and improper use of fuses does not result in fire on the premises, it is the writer's opinion that this is due to the fact that other conditions do not prevail to make these risks unduly hazardous. Overfusing is sometimes resorted to, principally on branch circuits for which the National Electrical Code permits only 10-ampere fuses. The carelessness and ignorance of the individual are largely responsible for much of the incorrect fusing. The ingenuity of the mechanic is apparent in the better classes of shops. The penury of the purchasing agent and the desire of the employee to keep down expenses is responsible for much bridging of fuses and tampering with them.

In the following table the numbers at the heads of the columns refer to the corresponding occupancy number in the above report.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
Approximate number of fuses used	550	.....	.....	1000	.....	450	500	.....	.....	200	.....	300	156	.....	250	.....	650	.....	.....	.....	.....	350	1500	40	.....	50	.....
Approximate number of cartridge fuses used	400	.....	.....	1000	.....	400	500	.....	.....	164	.....	270	120	.....	.....	.....	.....	.....	.....	.....	.....	.....	750	.....	.....	.....	.....
Number of plug fuses used	150	.....	.....	.....	.....	50	.....	.....	.....	36	.....	30	36	.....	.....	.....	.....	.....	.....	.....	.....	.....	750	.....	.....	.....	.....
Total number refilled Economy fuses used	10	10	.....	No.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	No.	.....	.....	.....	.....
Uses Economy fuses	Yes.	Yes.	.....	No.	.....	Yes.	Yes.	.....	Yes.	Yes.	Yes.	Yes.	Yes.	Yes.	Yes.	Yes.	Yes.	Yes.	Yes.	No.	No.	Yes.	Yes.	Yes.	Yes.	Yes.	Yes.
Uses other than Economy refillable fuses	No.	No.	.....	No.	.....	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	Yes.	Yes.	Yes.	No.	No.	No.	No.	No.	No.	No.	Yes.
Number refilled Economy fuses on hand	10	10	.....	No.	.....	.....	.....	.....	.....	.....	18	.....	50	.....	20	.....	100	.....	.....	.....	.....	.....	75	12	100	.....	.....
Approximate number Economy fuses in stock	10	10	.....	No.	.....	.....	.....	No.	.....	60	42	12	.....	.....	20	.....	100	.....	.....	.....	40	.....	.....	12	.....	.....	.....
Likes nonrefillable fuses best	Yes.	Yes.	.....	.....	Yes.	.....	No.	.....	No.	No.	No.	Yes.	No.	No.	No.	No.	No.	No.	Yes.	No.	Yes.	No.	.....	No.	No.	.....	No.
Likes Economy fuses best	No.	No.	.....	.....	No.	Yes.	Yes.	.....	Yes.	Yes.	Yes.	No.	Yes.	Yes.	No.	Yes.	Yes.	No.	No.	Yes.	No.	Yes.	.....	Yes.	Yes.	.....	Yes.
Bridging nonrefillable fuses	.....	Yes.	.....	No.	.....	No.	.....	.....	No.	No.	Yes.	No.	No.	No.	No.	.....	No.	Yes.	No.	Yes.	No.	No.	No.	No.	No.	No.	No.
Customer refills nonrefillable fuses	No.	Yes.	.....	Yes.	.....	Yes.	.....	.....	No.	No.	No.	No.	No.	No.	Yes.	.....	No.	No.	No.	Yes.	No.	No.	No.	No.	No.	.....	.....
Contractor refills nonrefillable fuses	.....	No.	No.	No.	.....	No.	.....	.....	No.	No.	No.	No.	No.	No.	No.	.....	No.	No.	No.	Yes.	Yes.	No.	No.	No.	No.	.....	.....
Fuse manufacturer refills nonrefillable fuses	.....	No.	Yes.	No.	.....	No.	.....	.....	No.	No.	No.	No.	No.	No.	No.	.....	No.	Yes.	Yes.	No.	No.	No.	No.	No.	No.	.....	.....
Refills Economy fuses improperly	No.	.....	.....	.....	.....	Yes.	.....	.....	Yes.	Yes.	No.	No.	No.	No.	No.	No.	No.	Yes.	No.	Yes.	No.	No.	Yes.	No.	Yes.	No.	No.
Trouble with Economy fuses	Yes.	No.	.....	.....	.....	No.	No.	.....	No.	No.	Yes.	Yes.	No.	No.	No.	No.	No.	No.	Yes.	No.	.....	No.	No.	No.	Yes.	No.	Yes.
Loose contacts Economy fuses	Yes.	No.	.....	.....	.....	No.	No.	.....	.....	Yes.	Yes.	Yes.	No.	No.	No.	No.	No.	Yes.	Yes.	No.	No.	No.	No.	No.	No.	Yes.	No.
Use Economy fuses with powdered filler	Yes.	Yes.	.....	No.	.....	Yes.	Yes.	No.	Yes.	Yes.	Yes.	Yes.	Yes.	Yes.	Yes.	Yes.	Yes.	Yes.	Yes.	Yes.	No.	Yes.	Yes.	Yes.	Yes.	Yes.	Yes.
Use Economy fuses with asbestos	No.	No.	.....	No.	.....	No.	Yes.	No.	No.	No.	No.	No.	No.	Yes.	No.	No.	No.	Yes.	Yes.	No.	No.	No.	No.	No.	No.	.....	.....
Use Economy fuses without filler	No.	No.	.....	No.	.....	No.	Yes.	No.	No.	Yes.	Yes.	No.	Yes.	Yes.	No.	No.	No.	Yes.	Yes.	Yes.	Yes.	No.	No.	No.	Yes.	.....	.....

INSPECTIONS [8] IN PITTSBURGH, PA.; CINCINNATI, OHIO; AND CLEVELAND, OHIO

PITTSBURGH, PA.

1. The result of a series of tests made by a power company to determine the relative operating efficiency of various inclosed cartridge fuses indicated that the Economy fuses were the best available fuse for use on their industrial power circuits. This was based on rating, reliability of contacts, and successful operation.

The power company maintains a rigid inspection service which varies from once a year for a 5 horsepower industrial motor load to every 30 days for the largest consumers, such as steel plants and manufacturing companies. In this service their inspectors report that no abuse of Economy fuses has been found, while hack-saw blades, wire solder, solid copper wire, and other articles are used to replace blown approved fuses.

Trouble has been experienced due to heating at the cut-out contacts. It has been found that some of the approved cartridge inclosed fuse elements break very close to the copper contact pieces, and therefore a copper arc is established in such cases. This arc has different characteristics from that of the metal of the fuse element, and this condition has caused difficulties in the Pittsburgh field from charring fiber tubes. In a particular risk, after one "blow," smoke began coming through the floor, and the resultant excitement nearly caused a panic. It was found the fiber tube had been ignited by the copper arc.

The power company representative indicated that he believed a reliable fuse renewable by the user was desirable and should be considered He questioned if the general user would take the time to develop ways to abuse a readily renewable fuse. It was stated that in their field tests they had not found an approved fuse which would carry 100 per cent rating continuously for two hours; about 75 per cent would not carry as high as 50 per cent rating for that time. This situation has led him to design a new type of fuse block.

A foreman of the power company said he believed the Economy fuse would introduce no greater risk in general service than the approved cartridge inclosed fuses. He believed that a man who wished to abuse a fuse installation would do so no matter what the mechanical construction.

2. The assistant purchasing agent of a large bridge company stated that the Economy fuse was being used by them at three of their plants.

3. The electrical engineer of a metal manufacturing company felt quite positive the Bureau should be able to determine such questions without consultation with users. He finally said that the company was a small purchaser of Economy fuses, in an experimental sense mostly. He could give no direct data, but stated the use must be very limited else he would know more of it. He did not care to go into more details, and stated that he did not wish to be quoted to either insurance or fuse manufacturing companies.

4. The engineer for a 10-story office building stated that he bought four 450-ampere, 250-volt Economy fuses seven months ago. I saw one in use in a main fuse block of the building. They were bought for trial. The first one installed was still intact.

The Economy Fuse & Manufacturing Co. had hoped to install their fuses throughout the building. However, the owners would not consider them. It is doubtful if their use in this risk indicates anything of value.

In this risk a fine example of heating at contacts was found. The clips had been so heated that the temper was gone and a clamp was used to hold them in good contact against the fuse blades. Approved fuses were in use when this was done.

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[8] By H. S. Phelps, an assistant electrical engineer of this Bureau.

5. A large grocery concern stated that they bought about $75 worth per year of Economy elements of 15-ampere average size. These are used on circuits for operating meat grinders. The motors are frequently stalled and the cost of replacing approved fuses is too great. It depends upon which of their stores the installation is in whether the fuse is replaced by a man having some electrical knowledge. It was stated that in some stores it was done by the butchers using the grinders. It was doubtful if it could be said that any of the fuses were under the supervision of a man with considerable knowledge of such equipment. Approved fuses are used by them on circuits where fuses operate infrequently, but these are not refilled.

The companies carry standard fire insurance. They have never experienced any trouble from insurance inspectors concerning the use of Economy fuses.

The Economy fuses first used by this company were the type using a powdered filler. Since this purchase, however, the fuse company has notified them that a filler is no longer necessary.

6. The engineer of a hospital advised that he had about 500 Economy fuses of 10 to 15 ampere, 250-volt capacity. These effected a considerable economy in service. It was stated that refilling was done by him or under his supervision, and that previous to the use of Economy fuses approved fuses were not refilled by them, but frequently they soldered fuse wire onto the terminals.

It was stated that the cost of new elements probably was not in excess of $12 a year.

He thought the very great simplicity of the Economy fuse led to its proper use rather than abuse, as he felt that the average user was not naturally crooked and rather than devise wrong methods he would use the fuse properly. He also called attention to the fact that with few exceptions the approved fuses had screws holding the end ferrules which made it very easy to attach a piece of wire, while the Economy fuse did not offer such an opportunity. He said he believed a refillable fuse put into general service would not be abused.

The purchasing department of the hospital stated that the Economy fuse had been chosen after consideration, and that a big saving had been made with satisfactory results. However, if another and more satisfactory fuse, renewable by the user, was developed or introduced, they would investigate it too.

7. The engineer of an office building has charge of a mixed occupancy. The building is a 10-story office building.

He does not use the Economy fuse, but has both Daum and Willett renewable fuses on several circuits where fuses blow frequently. On other circuits approved fuses are used. They make no effort to save old shells of approved fuses and return them for filling, as the supervision necessary to accumulate a large order is not warranted by the net saving.

It was stated that in an occupancy of this kind service is absolutely the first consideration, and, no matter what the type of fuse, it might become necessary to intentionally overfuse a circuit at times. The case of an elevator control circuit which has developed a partial ground was cited as an example. The engineer said that he did not believe a refillable fuse would be abused any more than an approved one, and in many cases it would be a distinct advantage to service to be able to renew them readily. It was really less hazardous, because it could be done properly and its inspection would be much more definite.

The local manager who had been in charge of a restaurant for seven years said that he had done all the purchasing, and to the best of his knowledge there had never been an Economy fuse in the place. He stated that he used the Northwestern renewable fuse on circuits where failures were frequent. The fuses in circuits on which dishwashing and potato-paring machines are used were of about 15 amperes capacity, and in case of a failure anyone in the kitchen refills the fuse. It was learned that neither city nor insurance inspection service objected and that the results had been satis-

factory. In circuits having infrequent failures the approved fuses are retained because of their lower cost.

He believed that a risk such as theirs would indicate that the general public would not abuse the renewable type any more than the approved fuse, as none of his employees knew anything electrical, and they refilled the fuse properly rather than devise means for doing it otherwise.

9. The assistant engineer of a department store said that they used a great many Economy fuses of the 10 and 15 ampere 250-volt rating. These are located mostly in elevator control and lighting circuits, where failures are frequent.

It was stated that in addition to the Economy fuses there were many approved fuses used in circuits not failing often. The Economy fuses have proved satisfactory to them, and it is their belief they would not increase the hazards if in general use. Refilling is done under supervision of competent men, and no effort is made to refill standard fuses either by the user or by returning them to the maker.

10. On the freight-elevator circuit in the office of an express company I found bare wire, probably fuse wire, though I am not certain, wrapped across the terminals of the fuse blocks.

11. The electrical engineer in charge of construction and operation for a large metal-manufacturing concern stated that a small number of Economy fuses had been installed in three of their plants. He stated that their use was so small that he could not give any data of value.

CINCINNATI, OHIO

1. The engineer for a telephone company said that about 2 per cent of the fuses used in their exchanges were Economy fuses and ranged from the smaller sizes up to about 70-ampere, 250 volts.

In general, approved fuses, D. & W. make, are used, but in circuits where great reliability and continuity of service is required they do use Economy fuses. It was stated that for certain heavy circuits they would use them now if they were available with the special terminals required. For a time it was their practice to save the shells of blown approved fuses for returning and refilling, but the cost was so prohibitive that now a blown fuse is simply so much scrap material.

He said that their refilling of Economy fuses was under competent supervision and had been perfectly satisfactory. He was not aware that the fuse was not a general approved one, and said that if it invalidated their insurance he would be forced to discard it. However, he indicated that in his experience he could not see where the Economy fuse in general use would be a greater risk than the approved. He thought that the person who abused a fuse now had either a financial or other point in mind, and therefore would abuse any fuse if he desired. In favor of the Economy fuse, he mentioned the fact that there were no binding screws whereby a wire could be readily attached to the ferrule, as in so many other makes. He also stated that in general the Economy fuse construction and finished product appeared to be more robust than any other fuse on the market.

2. An ice company had 6 Economy fuses out of a total of 12 fuses installed on a small obsolete generator equipment. No general conclusions could be drawn from this installation. Fuse wire or copper wire had been used freely to replace inclosed fuses, this being wrapped about the clips on several blocks. The assistant engineer stated they probably would not buy any more fuses, but would strap the clips together with wire.

It would appear that any type of fuse would be subjected to any degree of abuse or misuse in this plant. The Economy fuses had been in service about a year without blowing, hence the occasion to replace them had not arisen.

3. The engineer for a baking company has about 500 Economy fuses in use. They range from 10 to 250 amperes at 250 volts. Their service has been very satisfactory,

and it was stated that for use under intelligent supervision it was felt they were really better than an approved fuse.

When standard fuses were used no effort was made to refill them, as the cost of collecting the empty cases offset the saving over a new fuse.

The engineer stated that in general use it appeared to him the Economy fuse might be abused, due to the ease of opening them. He also felt that the inspection service could not take sufficient pains to learn if they were fused wrongly. As against that he said there was nothing to prevent a buyer using heavier approved fuses, and where service had to be maintained he knew of nothing to prevent abuse of any fuse.

4. The engineer of a hotel stated that there were so many small parts in the Economy fuse that with a large installation they must be abused. With the investment made he believed no one would throw the shell away when one part was lost, and therefore a piece of wire would be soldered on. He is not a user, but knows of the fuse.

5. The electrician of one of the hospitals has about 300 Economy fuses in use. They range from 10 to 60 ampere, 250 volts. They have proved satisfactory and a great saving in expense as well as time in placing a circuit back in service. The majority of the fuses at this plant are 10 and 15 ampere rating.

It was stated that frequently they had 100 fuses blown a week. Most of these are located in the kitchen, and fail because of carelessness in handling of potato-paring, ice-cream, and similar machines. In such cases the ordinary kitchen employee replaces the fuse satisfactorily.

He was formerly an electrical inspector in connection with fire insurance. He said that, based on his experience as an inspector, he could not see how the Economy fuse would be a greater hazard or be abused any more than an approved fuse.

6. The engineer and electrician in charge of a glass manufacturing company's building informed me that they had abandoned the Economy fuse and now used the Multi-refillable fuse.

It was learned that trouble had been experienced from Economy shells becoming charred at the ferrules because of contact heating. Also, in bending the fuse elements down in the 10 and 15 ampere sizes they frequently broke off, while above 100 amperes it is believed the Economy is as good as any fuse.

The engineer is not favorable to the Economy fuse, based on past experience and results obtained from other types.

7. A carpet-cleaning company was listed as a purchaser of Economy fuses. It was not possible to verify the use of Economy fuses at their plant. The various panel boards that were inspected were fused with open fuse wire and in general greatly overfused. The engineer said they were not buying any more fuses, as fuse wire was so much cheaper.

8. An engineer of a street railway company is just introducing Economy fuses on their system. He believes the hazard between approved and Economy fuses is about equal, while the economical gain would appear to be very marked. He said that he would feel it unfortunate should there be a check placed upon the approval of the Economy fuse.

9. At a wood-working plant it was learned that Economy fuses had been used for some time. They have 40, most of them being 15-ampere, 250 volts. It was stated that they would frequently blow 15 fuses a day. This high rate is due to the difference in timber due to seasoning and can not be determined before placing the timber in a machine. For this company the Economy fuse has proved to be very satisfactory, a big saving, and no apparent added hazard. Anyone using a machine replaces a fuse in case of a failure. Their experience would indicate that when the user is given an opportunity to refill readily and correctly, a renewable fuse will not be abused to the extent that the approved fuse has been. No economy had been shown by saving approved fuses for refilling.

10. An electrical inspector for a fire-prevention bureau stated that in his belief the Economy fuse was a step in the right direction. Their use has proved thoroughly satisfactory, and since the present argument arose he stated that he had cautioned his inspectors to pay especial attention to risks using Economy fuses. The operating experience gained has warranted retaining them in service.

He stated that he believed a fuse readily renewable by the user was demanded, its use would eventually reduce the abuse of fuses, and that so far as his experience was a criterion the Economy fuse was a step in that direction.

CLEVELAND, OHIO

1. The purchasing agent for a branch of a can-manufacturing company stated that they had used Economy fuses for only a short time, in an experimental way only, and therefore it could not be considered of value and he did not care to state more.

2. The engineer for a machinery company stated he had about 80 fuses in use, being mostly old open-link type, but a few Economy fuses had been used of 60-ampere, 250-volt rating. These had given satisfactory service. It appeared to him that the use of a fuse readily refillable by the user did not introduce any greater hazard. He felt that the overfusing of a circuit eventually caused the operator much more trouble than fusing properly.

For a long time they were unable to buy Economy fuses. The dealers appeared to be unwilling to sell them and usually replied that they were sending an approved fuse to fill their order. Finally Economy fuses were obtained and had proved satisfactory. It was indicated that as soon as business conditions improved Economy fuses would be used throughout their plant.

3. The master mechanic for an electric railway company purchased a trial order of 5 and 10 ampere, 600-volt Economy fuses for use on car-lighting circuits. Before placing them in service a rough test was made by placing samples of each size in series with a 550-volt lamp bank. The 5-ampere fuses opened the circuit readily but with considerable noise, while the 10-ampere fuses were completely demolished, wrecking the fuse block as well. The fuses never went into service.

The Johns-Pratt "Noark" fuse is used by them in general and has proved entirely satisfactory. So far as known they are mechanically secure.

An effort has been made to save the old cases for refilling by an outside interest. The chief difficulty has been in obtaining the old shells in sufficient quantities, as the car men throw them away.

This case was the only one found where it was attempted to use an Economy fuse of a 600-volt rating, and they were unsatisfactory.

4. An engineer for a bag company is not using Economy fuses as their new plant was equipped with approved fuses by the contractor. In their old plant he had about 130 Economy fuses, ranging from 10 to 75 amperes, 250-volt rating. These were very satisfactory. All refilling was done under his supervision. No effort was made to refill approved fuses. As rapidly as the approved fuses of the new plant fail, he intends to replace them with Economy fuses of 10 to 75 ampere rating, and it will make an installation of about 200.

In comparing the two types of fuses he said he believed the Economy fuse was thoroughly good and reliable under supervision and proper replacing. In his opinion, however, the general use of a fuse readily renewable by the user would be more of a hazard than the use of approved fuses. He realized that any kind of fuse would be misused, but was inclined to believe that a fuse which invited being opened would eventually lead to a greater amount of trouble in general use than the approved fuse. However, for factory service he would readily indorse their use.

5. The engineer of a cloth-manufacturing company said that they had about 800 fuses in use, of which about 20 were Economy fuses. Of the latter he has some 200-

ampere, 250-volt fuses which are very satisfactory and readily and safely refilled. Refilling of Economy fuses is done under his supervision, and approved fuses are discarded when blown. He will place more Economy fuses in service at an early date.

For isolated plant work he feels Economy fuses are very satisfactory and open to no more abuse than an approved fuse and introduce no more hazard. However, he feels that for general service the fact that they are readily accessible will eventually increase the hazard. He feels that the average inspector will be able to detect the general abuse of approved fuses, while with one which may be opened and in which abuse may be concealed the inspector can not hope to open each fuse installed in a risk.

6. One engineer of an office building is not very well informed as to the success of the Economy fuse in their building. However, he believed another engineer had kept a log of the operating results of their Economy fuses and the fact that they had about 100 fuses of 10 and 15 ampere capacity would indicate they were satisfactory. On their station switchboard I found four 100-ampere Economy fuses out of a total of some 80 fuses.

He said he was in no position to judge what the relative hazard would be if a renewable fuse was given general recognition.

To summarize the information obtained through this trip of inspection, I would say that in 10 interviews it was stated that their belief was the general use of Economy fuses would not introduce any greater hazard than approved fuses. In 4 interviews it was stated that under competent supervision, as that provided in an isolated plant, the risk would be no greater, but that for general risks the hazard would be increased.

Two parties visited had not experienced satisfactory results. In one instance trouble had been experienced through inability to maintain satisfactory contact of the fuse element in the ferrule type fuses, while in the other case the fuses had been subjected to a rough test before placing fuses of a 600-volt rating in service. Under this test they failed, and for the 10-ampere size they blew to pieces and wrecked the fuse blocks, hence they were never placed in service.

In five cases fuses had been purchased and installed experimentally and in so small a number that it has been considered their information is not to be considered as having any weight.

Three parties were called upon who do not use the Economy fuse. Two other parties were visited who do not use Economy fuses, but as their risks were typical their opinions were worth seeking.

MISCELLANEOUS INSPECTIONS

In addition to the inspections described in the foregoing a considerable number of informal inspections were made from time to time as opportunity afforded by engineers of the staff of the Bureau of Standards. Owing to their disconnected character, however, these inspections are not reported in detail here. The evidence obtained in such inspections, however, has been duly considered, and in general it may be said to agree with the results of the inspections recorded above. In some of these informal inspections it was found that many of those users who spoke very favorably of Economy fuses, in so far as their experience with them was concerned, were disposed to take the view that it would not be wise to approve these fuses for general use except in the hands of experienced electricians. It was further brought out in

these inspections that some users do not understand what is meant by satisfactory performance of fuse. In some instances a satisfactory experience was reported with the fuses, but detailed questioning brought out the fact that numerous explosions of the cartridges occurred under regular operating conditions.

GENERAL SUMMARY OF INSPECTIONS

On account of the detailed character of the evidence brought out in the inspection trips, it is difficult to obtain an accurate idea of the results of these inspections except by perusal of the complete report. However, an examination of these reports reveals a number of important facts of a general nature.

1. Economy fuses have up to the present time been used for the most part by the better class of fuse users, who are more competent to handle them than the average fuse user might be. Hence the experience to date can not be said to be of a general character.

2. Some who formerly used Economy fuses no longer do so apparently because they were not satisfied with the results obtained, and in general the present users are more cautious in their praise of Economy fuses than would be expected if no difficulties in their use has been encountered.

3. There is a great deal of abuse of approved fuses, and also some abuse of Economy fuses, but there is undoubtedly less abuse of the latter than of the former on the part of the average user. In interpreting this statement, however, it should be borne in mind, as mentioned above, that Economy fuses have not as yet been widely used by the less responsible classes of fuse users.

4. Superficial statements of users of Economy fuses were often more favorable than the evidence brought out by careful questioning of the user. It was also revealed that what users consider satisfactory operation can not always be considered so from the standpoint of fire and accident hazard.

5. The abuse of approved fuses may take a great variety of forms, many of which make it absolutely impossible for the fuse to perform its proper function, thereby introducing a serious fire or accident hazard either by lack of protection for circuits and apparatus or by danger from the operation of the fuse itself. The chief form of abuse of approved fuses appears to be the practice of bridging the fuse on the outside with heavy fuse wire, copper, or iron wire, or putting a nail or wire through the center of the cartridge. Occasional forms of abuse met with consist of taking out the filler and pouring the fuse cartridge full of melted solder

or placing a bolt through the cartridge. Some of these are extremely difficult to detect on superficial examination. In certain occupancies the tendency to abuse approved inclosed cartridge fuses is surprisingly great. In one inspection trip reported above, 1 out of 7 fuses of a total of 379 approved fuses examined was found to be improperly filled. In other inspection trips, however, the tendency to abuse such fuses was found to be relatively small, indicating a wide diversity of practice in the different localities inspected.

6. The evidence obtained in these inspections shows that there is a large amount of refilling of approved fuses by small shops, which make this a regular business, although the manufacturers advertise that such fuses can be refilled by them and offer to do it for the users. This, however, is often not very convenient, and it is much easier to have the work done by some local mechanic, especially when a small stock of fuses is carried. When fuses are refilled in this way in small shops there is no assurance that they will be properly refilled, and the evidence shows that in some cases they are as badly abused in refilling as when the users themselves refill them with improper fuse links or improper wire.

7. The evidence gathered in these inspections shows that while there have been numerous cases where individual Economy fuses have failed in various ways to give satisfactory performance, nevertheless no evidence available indicates that the fires or accidents resulting from such failures exceed those which would have occurred with approved fuses; so that it can not be contended, except by inference, that the use of Economy fuses up to the present time has actually increased the fire or accident hazard.

8. The testimony of users of Economy fuses, although not uniformly favorable, seems to indicate that in the main those who begin using Economy fuses continue to do so, which implies satisfactory service in the majority of cases. This should not be adopted without reserve, however, as indicating that fuses of this type should be approved for general use for several reasons. First, most of the experience to date has been with a type of fuse which differed in several respects from the type now being sold. One very important change has been the abandonment of the use of the powder filler, the use of which unquestionably gives better performance than is obtained with the present type of unfilled fuse. Notwithstanding the fact that the use of this filler was abandoned by the Economy company about a year ago, the inspectors of the Bureau of Standards found a great many of

such filled fuses still in use. The second consideration is that the experience is for the most part in connection with installations in which the fuses have been used under the supervision of competent electricians, and in a large proportion of the cases also the fuses have been used in closed cabinets, which would practically eliminate fire or accident hazards that might otherwise be involved in their use. A third element involves the fact that favorable testimony may often be due to lack of appreciation of what constitutes satisfactory performance, specific instances of which are pointed out above.

It appears from the foregoing that the results of the inspections made by the Bureau of Standards, while they do not supply evidence that could properly be used as a basis for condemning the Economy fuse, have nevertheless brought to light certain facts which are in accord with other evidence set forth in the foregoing report which indicates that there is still enough doubt regarding the practical operation of the Economy fuse to make it advisable to proceed cautiously in the extension of the use of this type of fuse in order that adequate experience may be gained regarding its performance under all service conditions without creating conditions that might involve a material increase in the fire or accident hazard.

VII. STATEMENT SUBMITTED BY ECONOMY FUSE & MANUFACTURING CO. SUBSEQUENT TO HEARING

CHICAGO, *October 20, 1915.*

BUREAU OF STANDARDS,
Washington, D. C.

Re Underwriters' Laboratories vs. Economy Fuse and Manufacturing Co.

FUSE QUESTION

GENTLEMEN: We expect to hear from the Bureau if any additional evidence or arguments are filed or made which are to have any weight with the Bureau, informing us of the nature and points to be answered.

In the meantime, because of the great amount of effort expended on tests since the extension of time was granted, and because of certain matters which have come to our attention during the progress of these tests as to the stress placed or to be placed by the representatives of the standard fuse makers upon phases of the question submitted for answer, which were not contemplated by either the Laboratories or the Economy Fuse & Manufacturing Co., and which do not enter into the decision of the question submitted, we are taking the liberty of again addressing the Bureau to place before it once more, in concrete form, what it is the Bureau has been called upon to answer.

We refer the Bureau again to our letter of July 27, 1915, and our former arguments.

It is a matter of the utmost importance to this company that certain salient points be not overlooked.

First, that it is the *use* of the Economy fuse which is in question. Field experience has been the constant cry.

Second, that the Economy fuse is not to be discriminated against by comparison with a favored few of the standard makes.

As to the first, it must be borne in mind by the Bureau that the dispute is between the Underwriters' Laboratories (Inc.) and the Economy Fuse & Manufacturing Co., because of claimed unjust discrimination against the Economy fuse by reason of its renewable features.

The Underwriters' Laboratories, as the one authority in the insurance world, have the measuring devices for testing the fuses, and fuses which meet their requirements must be passed by them or discrimination exists. They have measured the Economy fuses as they measure all other similar fuses, and have reported that the Economy fuse complies in all ways with the requirements so as to make it standard thereunder, with the exception that the renewable feature distinguishes it in such a way as to render it necessary that it be shown that this feature has not rendered the fuse in use a greater fire hazard than other fuses designed for the same purpose.

The Laboratories are committed to the opinion that from such evidence as they had such renewable features not only would not make the use of the fuse a greater fire hazard but would tend to reduce the fire hazard incident to the use of so-called non-refillable types because of the frequent abuse of this type which the easy renewable features of the Economy fuse seem to remedy to at least some extent.

The question is, "Has it been shown that the *use* results?" which means and was intended to mean under actual existing conditions in the field.

That the use of Economy fuses *does not* result in any greater hazard has been amply shown.

(*a*) Standard fuses are continually abused so as to cause a great fire hazard.

(*b*) Economy fuses are so usually properly refilled that the hazard from the improper use of standard fuses is greatly reduced.

(*c*) The hazards seldom, if ever, result from violent operation of the fuse itself, but the chief hazard comes from the abuse of the fuse which destroys its use as a protective device. The accident occurs beyond the fuse because it does not perform its proper function.

Disruptive effects in operation in the fuse itself do not constitute the real danger.

Violent operation, if the fuse immediately opens the circuit, is much less a hazard than less violent operation with more or less sustained arc.

Stress has been laid on the changes in design of Economy fuses. No stress is laid on the changes in design of standard fuses which admittedly exists. Vide, D. & W. and statements made by standard fuse maker representatives at the recent tests, and see samples furnished by makers for recent tests.

No change in *used* designs in Economy fuses have resulted in an unfavorable report from the Underwriters' Laboratories after tests.

The changes go only to the effect on the user in refilling.

They have consisted *solely* in the gradual elimination of the filling material, the securing of metal to metal pressure for contact, the adoption of the drop-out link.

The other changes referred to are admittedly minor and unimportant.

The refillable features have always been the same, changes tending only to greater ease in refilling.

From the *use* standpoint the experience has been since 1912.

The elimination of the filling material is an obvious aid to proper refilling. It *does away* with intentional or unintentional forgetfulness.

The metal-to-metal pressure in the ferrule type and the drop-out link equally obviously can have no relation to use as to proper refilling.

TEST COMPARISON

As far as real scientific fuse tests are concerned, recent experiments have shown this field has only been touched and that there are many uncertain factors, and in the present stage of development in test work and reading aright the results for practical application they should have little weight. Fuses to be tested should be carefully examined as to construction, both as to filling material and fuse element, to know that they are the ordinary marketed product. There are too many uncertain factors to render *comparative* tests of scientific value.

As was stated in our letter of July 27, in granting the extension of time:

> The standard fuses are gauged by the Laboratories and the Laboratories have gauged the Economy fuses by the same tests and reported on every size and voltage except the 600-volt fuse 60-amperes and over, and these tests and reports show that the Economy fuses meet the requirements for listing in the same way that standard fuses do, but the question which the Laboratories refused to pass upon was, Does the use of Economy fuse show an increased fire hazard over the use of the standard listed fuses by reason of its renewable features?

Our observation at the recent tests in Boston and Chicago was that on the 250-volt line the disruptive effect was present in all but two makes; in one it was vastly more severe and larger in percentage than in the "Economy."

In the rating tests our information is that Economy fuses stood the tests better than any make tested, except two which had no failures where the Economy had one only.

In the Chicago 600-volt tests the Economy 30-ampere and 400-ampere were fully the equal to any tested; while the disruptive effect of the intermediate sizes was severe, a great many of the standard fuses were mutilated and the difference in operation was largely one of severity of the disruptive effect, not the lack of it on the one hand and the presence of it on the other.

A fuse which holds an arc is a far greater hazard in use than one which opens the circuit immediately, although the disruptive effect in immediately opening the circuit may in some cases be somewhat greater in violence. The oscillograms of the tests in Boston and Chicago speak far more effectively of the safety in the use of the Economy fuse because they show what actually takes place is the immediate interruption of the current as against the slower interruption or continued arcing shown in many of the standard makes which on blowing gave less offense to the eye and ear.

We have tabulated the results of these tests from the test sheets furnished by the Bureau, and give below a general summary: [9]

Test Records

250-VOLT LINE

Make of fuse	Number blown	Noise	Flash	Results	
				Ignited cotton	Mechanical failures
Economy	121	69=57%	46=38%	31=25.6%	11= 9.1%
II	46	44=95.6%	31=67.4%	7=15.2%	25=54.3%
V	57	34=59.7%	32=56%	5= 8.1%	2= 3.5%
IV	58	40=68.9%	11=19%	2= 3.4%	3= 5.2%
III	52	45=86.5%	35=67.3%	1= 1.9%	1= 1.9%
VI	64	34=53.1%	10=15.6%	.....	.....
I	57	51=89.5%	47=82.5%	.....	.....

[9] The following discussion was prepared by the Economy Fuse & Manufacturing Co. from the original test record before it had been studied and revised by the Bureau of Standards. The official interpretation of these tests by the Bureau will be found in Section V of this report.

Test Records—Continued

600-VOLT LINE

Make of fuse	Number blown	Noise	Flash	Results	
				Ignited cotton	Mechanical failures
Economy	103	51=49.5%	45=43.7%	29=28.1%	33=32.6%
II	71	52=73.2%	32=45.1%	5= 7%	12=16.9%
V	61	43=70.5%	42=68.7%	12=19.7%	7=11.4%
IV	49	42=85.7%	2= 4.1%	.....	.....
III	58	29=50%	18=31%	.....	.....
VI	62	31=50%	17=27.4%	.....	.....
I	60	54=90%	47=78.7%	1= 1.7%	17=28.3%

We wish to draw attention to the following facts:

That on the 250-volt line twice as many Economy fuses were blown as of any other make.

That all but two makes showed failures or mechanical disruption.

That all but two makes ignited cotton.

That there was flash in all makes.

That there was noise in all makes.

That II performance was in every particular worse than Economy.

That V performance was only slightly better.

That the "Economy" performance compares favorably with that of a majority of makes.

On the 600-volt line we point out:

That while "Economy" shows a higher percentage of failures, this is due largely to sizes between the "30's" and "400's."

As appears from the detailed tabulation following:

Economy 30's were the equal of any tested, and the 400's showed only one failure and the V showed one failure also, and in addition ignited cotton, whereas the II showed three failures out of five tested on the 400's and all three ignited cotton.

The "Economy" performance on "100's" and "200's" was 12 failures out of 14 blown, yet II showed 1 out of 3 on the "100's."

The "Economy" performance on "60's" was 13 failures out of 31 blown.

Of the I "60's," 11 were failures out of 17 blown, of II 7 were failures out of 20 blown, of V 6 were failures out of 15 blown.

On all tests of Economy fuses in series, the actual service condition in the use of all fuses, except on special service, usually in 600-volt railroad work, there was not one failure in any way.

The attention of the Bureau should not be diverted from the fact that the Economy fuse is not being compared to the most favored or the best of the standard fuses, but to the worst; if any approved fuse is as much of a hazard as the Economy in its use, it is sufficient.

Factory-refilled fuses are not tested.

Factory refilling of fuses is urged on users by insurance inspection departments, and is commonly practiced.

In the tests conducted, this company, in accordance with its agreement of submission with the Underwriters' Laboratories, has been but a passive onlooker; such active part as has been taken has been through courtesy to the department.

Neither the company nor the Laboratories have felt that they were being in any way gauged by these makers' tests, and have not for that reason gone into any defensive phases of the test situation.

Tests were satisfactory to the Laboratories.

The question is one of field experience as to the additional hazard, if any, in the use of a renewable fuse with the safe and easy renewable features of the Economy.

It was said at the hearing by Mr. Merrill, "Nothing that is wrong eventually prevails in America." It will continually come up until made right.

Is not that truism examplified in the experience of this company with this question?

That Economy fuses constitute a distinct extra fire hazard has been stated and repeated, it has been impressed upon the minds of users by insurance inspectors requiring their removal on this account, and the standard fuse makers have overlooked no opportunity to bring home the same cry.

Think of it! What article of commerce could survive such statements concerning it were they in any way true, and even though not true it would take an article of extraordinary merit to sell in the face of such condemnation.

What can the continuing and increasing use of the Economy fuses (see list of sales in the last six months below) in the face of all this, prove except that these statements are false, and that it is of exceptional merit and fills a definite need?

Sales From May 1, 1915, to Oct. 16, 1915, Inclusive

	3–30 A	31–60 A	61–100 A	101–200 A	401–600 A	Special	Total
250–v fuses	167 111	46 688	20 876	2 831	704	14	246 371
250–v links	279 456	105 722	59 025	11 228	890	1 050	500 436
600–v fuses	21 027	9 136	4 726	524	80	18	37 132
600–v links	75 885	35 133	15 438	1 238	132	1 175	136 511

One after another the insurance inspectors, who have taken the trouble to investigate the merits of the fuse and to study its use in the field and to compare it under test with other fuses, have acknowledged their error.

The users of fuses of all classes, large and small, after thorough trial, because of the statements made against the fuse, have come to standardize the Economy fuse.

What can all this mean except that the Economy fuse does not only constitute no greater fire hazard than other makes of fuses, but in reality is a safety device?

Respectfully,

Economy Fuse & Manufacturing Co.,
By A. L. Eustice, *President.*

VIII. EVIDENCE AND STATEMENT SUBMITTED BY MANUFACTURERS OF APPROVED FUSES, SUBSEQUENT TO THE FORMAL HEARING

A number of manufacturers of approved fuses submitted a considerable number of exhibits consisting of specimens of fuses, mostly of the Economy make, which had been subjected to more or less abuse in service, and also some fuses which had been subjected to their rated current for a stated period on test. There was also submitted by Guy Cunningham, representing several manufacturers of approved fuses, a statement summarizing the evidence in the case as viewed by him.

These exhibits and the statement by Guy Cunningham are given below. The arrangement of the exhibits and comments thereon are due to the Bureau of Standards.

LIST OF EXHIBITS SUBMITTED AS EVIDENCE SUBSEQUENT TO THE FORMAL HEARING

EXHIBIT A

H. R. Sargent, managing engineer, wiring supplies department, General Electric Co., Schenectady, N. Y., sends under date of November 1 the following fuses:

1. A 600-ampere 600-volt Economy fuse which was blown once and carbonized.

This shell has one thread completely carbonized and two places in the interior at approximately the position of the plates which clamp the fuse element to the leading-in conductor.

2. A sample refillable fuse, the tubing of which is in no way fitted to stand the strain generated with an inclosed fuse.

This fuse is not of the Economy type, and therefore is not considered in the investigation.

EXHIBIT B

Sixty-ampere 250-volt Economy fuse, with old-style cap construction, submitted by Guy Cunningham, under date of October 14, from Hartford, Conn. Fuse refilled with copper wire and filled with some light foreign material. The fuse is in good condition. It has apparently been in use for some time.

EXHIBIT C

Ten 30-ampere 250-volt Economy fuses, submitted by Guy Cunningham under date of November 4. Fuses were rated by the Bryant Electric Co. for not over 95 hours, on runs of less than 10 hours per day. Every precaution was taken that the current should not exceed the rated current.

These fuses in many cases had heat discolorations of the brass caps and screw plugs. In many instances the fiber shell was darkened. The caps in some cases were loose at the threads.

EXHIBIT D

Ten 60-ampere 250-volt Economy fuses, submitted by Guy Cunningham under date of November 4. Fuses were rated by the Bryant Electric Co. for not over 95 hours, on runs of less than 10 hours per day. Every precaution was taken that the current should not exceed the rated current. The characteristic discolorations of the caps, screw plugs, and shells were apparent, as in the case of the 30-ampere size, but more marked, and in two instances the charring resulted in the breaking off of a brass cap and threaded portion of the fiber.

EXHIBIT E

Four 250-volt 0–30-ampere size old style Economy fuses, submitted under date of October 30 by Guy Cunningham, sent to him by the Bryant Electric Co., who obtained them from a factory in Bridgeport, Conn. These are wrongly refilled with fuse wire. In two instances a filler, which was not present on examination, seems to have been used. All fuse parts are in good condition, although they seem to have been much used.

EXHIBIT F

Ten 60-ampere 250-volt Economy fuses, submitted by Guy Cunningham, under date of October 30. These have been run 97 hours at rated load. Four of these are badly charred at the fiber threads. The other six are not visibly weakened.

EXHIBIT G

Three 0–30-ampere 600-volt and one 0–30-ampere 250-volt old-style cap construction Economy fuses, submitted by Guy Cunningham under date of October 30, received by him from the D. & W. Fuse Co., who obtained them from a brewing company.

The threaded portions on these fuses are charred at one end. No discoloration of the caps is apparent.

EXHIBIT H

Ten 30-ampere 250-volt Economy fuses submitted by Guy Cunningham under date of October 30. These fuses were run 98 hours intermittently. In some instances the fuses appear to have had a shrinkage of the fiber cases, loosening the caps. With the exception of a few instances where the fiber seems to be darkened, no other deterioration can be observed.

EXHIBIT I

Two 60-ampere 250-volt Economy fuses submitted by Guy Cunningham from Chicago, and one 30-ampere 250-volt fuse of unknown make, but having refillable characteristics, submitted by Mr. Cunningham from Philadelphia, under date of October 30.

All of these fuses are stated to have been badly charred and apparently are in that condition. The 30-ampere fuse is not an Economy fuse, and therefore is not considered in this investigation.

EXHIBIT J

Three 50-ampere and one 60-ampere 250-volt Economy fuses with old-style caps, and one 30-ampere 250-volt Economy fuse, submitted by Guy Cunningham, under date of October 30, and obtained from a user in South Framingham, Mass.

These fuses are all badly charred at the threads and in all but two instances caps have been broken off.

EXHIBIT K

One 30-ampere, one 60-ampere new style, and one 60-ampere old-style cap 250-volt Economy fuses, submitted by Guy Cunningham under date of October 30. Mr. Cunningham received these from the D. & W. Fuse Co., who obtained them in Atlanta, Ga. They are stated to have been charred, but on inspection this is hardly perceptible. This fiber is similar to that in some of the Economy fuses submitted by the D. & W. Fuse Co., after aging, for short-circuit test. In no instance has appreciable charring occurred in these fuses. In one instance, however, the fiber has shrunk, leaving the cap somewhat loose on the shell threads.

EXHIBIT L

Ten 30-ampere 250-volt Economy fuses, run 95 hours at rated load by the Johns-Pratt Co., submitted by Guy Cunningham under date of October 30. It is stated that these fuses seem to be badly weakened. Putty marks are in evidence in some instances where thermometers were used to observe temperatures of the fiber shell. In every case the fiber seems to have been darkened, owing to heat. Three fuses are marked "blown on load" at 12 minutes, 26½ hours, and 63 hours' run, respectively." The fiber has shrunk appreciably in most instances, but only slight charring effect is observed.

EXHIBIT M

One 30-ampere 250-volt Economy fuse, submitted by Guy Cunningham under date of October 30, and received by him from Minneapolis, Minn. This fuse is noted as being burned out at terminals. This fuse on inspection was found to have been filled with two 30-ampere fuse links, one of which had been blown, but all parts of the fuse are in good condition.

EXHIBIT N

Ten 60-ampere 250-volt Economy fuses, submitted by Guy Cunningham under date of October 30. These fuses had been run 95 hours at rated load by the Johns-Pratt Co. They were stated to be dried out and visibly weakened. One fuse is marked "Defective terminal." On inspection this showed threads at one end of the fiber shell to have been stripped. Apart from a slight shrinkage of the threads on three of the fiber shells, no other deterioration could be observed.

EXHIBIT O

One 25-ampere 250-volt Economy fuse, submitted under date of October 30 by Guy Cunningham, after use in Kansas City, Mo. The fuse was marked overfused with double fuse link. One 25 and one 15 ampere link were employed. The fuse does not appear to have been defective in any way.

EXHIBIT P

One 60–100-ampere 600-volt Economy fuse, submitted by Guy Cunningham from Kansas City, stated to be refilled, with washers omitted. Inspection showed that the outer brass and leather washers had been omitted at both ends. All parts of the fuse are otherwise in good condition.

EXHIBIT R

This exhibit consists of five fuses submitted by C. H. Hill, chief electrical inspector of the Underwriters Association of the middle department. This was submitted in compliance with a formal request from the Bureau of Standards. Fuse tagged No. 1 is an Economy 60-ampere 250-volt fuse with old-style cap, in which material other than that for a standard fuse has been employed. Inspection revealed a broken washer and the use of iron wire as a fuse element. Fuse cartridge was in good condition.

Fuse No. 2 is a 60-ampere 250-volt D. & W. fuse and is likewise improperly refilled. Inspection showed a piece of very heavy fuse wire soldered between the caps, with no filling present. The solder at one end of a cap was melted away.

Cartridges Nos. 3 and 4 are of the 60-ampere 250-volt Economy make. It is stated that the Economy company advised the failures were due to material which they originally used but subsequently abandoned. The fiber shells only are submitted and show a decided charring at the threads. Indications are that they have been repeatedly blown. The appearance of the fiber is very similar to that used by the Economy company at the present time.

A 60-ampere fuse element accompanied Nos. 3 and 4 and is badly fused at the ends where the contact was made.

No. 5 is a standard D. & W. screw type fuse plug in which the fuse element has been replaced by a lead washer and a galvanized-iron pipe coupling, indicating the extent to which a plug fuse may be misused.

EXHIBIT S

Two 60-ampere, 250-volt Economy fuses which were aged and submitted by the D. & W. Fuse Co. during the short-circuit tests made by the Bureau at Boston, Mass. These two fuses were not blown by the Bureau at that test, but were saved because of the apparently different type of fiber used as compared with the type which was supplied by the Economy Fuse & Manufacturing Co.

STATEMENT SUBMITTED BY GUY CUNNINGHAM, ATTORNEY FOR MANUFACTURERS OF APPROVED FUSES

1. *General Statement.*—In response to your letter of September 27 to the Chase-Shawmut Co. and other letters of a similar tenor to other makers of approved fuses and the request of Mr. McCollum at Chicago, I have considered the tests made at Boston and Chicago in connection with the oscillograms and make the following suggestions on the whole matter:

This letter is filed in behalf of the D. & W. Fuse Co., the Chase-Shawmut Co., the Johns-Pratt Co., and the Bryant Electric Co. I have no doubt that the Chicago Fuse Manufacturing Co. and the Detroit Fuse & Manufacturing Co. may agree with these statements, but I am not actually retained by them and have had no opportunity to consult them before filing this letter. I wish further to explain that owing to the

fact that the oscillograms were only received from Chicago by me this morning, October 28, that I have been obliged to write this letter in a great hurry.

It is apparent from the tests both in Boston and Chicago that the conditions imposed by the Underwriters are easily met by all fuses properly designed and made. This appears from the fact that three makes of fuses of the filled type operated more than 99 per cent perfect, while the Bryant fuses operated perfectly, except in the 30 and 60 ampere sizes, at 600 volts. The Union and Arkless fuses also showed defects in operation in certain classes. The Union and Bryant companies had both been warned of these defects by the Underwriters and were bound to correct them and were doing so when the tests occurred. The fact of the existence of defects in certain classes of fuses, which the Underwriters had directed the manufacturers to correct, is no ground for saying that the Underwriters should approve the Economy fuse, which operated much worse than the Union and Arkless fuses. The proper action for the Underwriters is to withdraw the approval of any fuses which have been approved and are later found not to meet the tests and to refuse approval of those which do not meet the tests.

2. *Economy Fuse on Short Circuit.*—The action of the Economy fuse under the tests imposed by the Underwriters' conditions was, on the contrary, such as to prove that fuse unable to meet the Underwriters' requirements. The operation in more than one-third of the cases was dangerously defective either in igniting cotton or exploding the cartridge or blowing off the ferrules.

It is clear beyond question therefore from the Chicago tests that the Economy fuses do result in a greater fire or accident hazard than the use of the fuses approved by the Underwriters in cases of a severe short circuit. The possibility of such a severe short circuit is exceptional, but a fire or accident loss is always exceptional. Insurance rates are frequently much less than 1 per cent and what the Underwriters strive to provide against is against risks which will cause fire once in a hundred years. Unless all the risks of fire added together in a plant insured at considerably less than 1 per cent are so small that a serious fire will not occur more than about once in a hundred years, the insurance companies must raise their rates. Accordingly the questions here is not whether the Economy fuse may be used safely for one day, one week, one month, or one year, but whether in the course of fifty or one hundred years steady use of Economy fuses will not result in fire or accident more often than the approved fuses. Such a greater risk is not to be regarded as slight in the eyes of the Underwriters, and no matter how slight the increase the Bureau has no right to disregard it under the terms of the arbitration. If the Economy fuse operates worse on severe short circuit, as it undoubtedly does, that in itself proves the case of the Underwriters.

3. *Severe Inductive Kick of Economy Fuse.*—The oscillograms show that when there is a normal amount of inductance in the circuit, as at Boston, the Economy fuse on blowing sets up dangerous oscillations and shows frequently a dangerously high inductive kick. This punctured the voltmeter in one case in Boston. On the other hand, the standard fuses show no dangerous oscillations and the inductive kick can be kept within any desired bounds. The Bryant fuses operated perfectly at 250 volts, seldom showing a voltage kick of more than 30 or 40 per cent above normal.

Accordingly the Economy fuse is in this respect also a greater fire hazard than the approved fuses. It is to be remembered that the effect of this kick may show anywhere in the line, even in the most unexpected places, as in the voltmeter at Boston. The danger is exceptional, but that is what the Underwriters have to exclude to give 1 per cent rates.

4. *Economy Casing Chars Quickly and Badly.*—The tests further showed that as soon as the fiber casing of the Economy fuse has been subjected to the heat caused by running a comparatively short time at normal load, the casing will be so weakened

that the fuse will either actually burn through or explode on short circuit or blow off its end caps.

This charring of the Economy casing, on a very short run, at normal load, is usually due to a poor contact, due to the fact that the Economy fuse, in order to be made readily refillable by the user, relies upon a screw contact.

In a former type of fuse placed on the market by the Economy company, and now in use in very large quantities, innumerable cases of the burning off of the end cap have occurred, and I am about to send to the Bureau a large number of samples of such burning. In considering the question of approving Economy fuses, it is proper for the Underwriters to note that these fuses are left in use by the Economy company and are not replaced until they burn up.

In the present type of fuse, a smaller percentage of charred tubing occurs, and in the fuses run at full load by the Bureau of Standards that percentage was abnormally small. The percentage of charring obtained in fuses tested by Mr. Downes was, on the contrary, abnormally high. As the Bureau found, differences in fiber caused part of the trouble, but, also, we may assume, without implying any impropriety by the Economy company, that the fuses supplied to the Bureau of Standards were assembled with great care by an expert, thus insuring the correct placing of the links and a perfect contact, while the fuses which are actually on the market are liable to improper setting up, even in the Economy factory, and will, in many cases, char from a bad contact.

I propose to send to the Bureau 60 fuses run at full load, which show a very high percentage of charring and serious deterioration of the fiber, in a run of less than 100 hours at the rated load. I shall also send a number of fuses taken from use which show such charring. The tests show that such weakened fuses have little or no reliability on short circuit, while standard fuses, run at the rated load for the same period, would operate without difficulty.

5. *Economy Fuse Used Until it Burns Up.*—In this connection we must remember that the Economy fuse is made to be used until it is worn out, and this is what happens to it in practice. In going into factories we have found, in most cases, that the majority of fuses in use were of the old types made by the Economy company, which will usually char the fiber as soon as run for a substantial period at the full load. If run, as frequently happens, at less than normal load, they may last for many years, unless there is a poor contact, but all such fuses are steadily deteriorating and will be used until they burn up.

All the foregoing dangers from the use of Economy fuses were clearly proved to exist by the tests at Boston and Chicago.

This danger is not exceptional. Every Economy fuse is out to be used until it burns up. At a tissue-paper plant at South Framingham, Mass., the Economy company replaces the fuse cases which have burned, but leaves in the others of the same type, and regularly a number of those smolder off. These have not yet caused a fire, but their use in a tissue-paper plant can scarcely be argued as a trivial hazard. Such is the natural result of using a fuse advertised to last forever and so designed as to char in at least 25 per cent of cases when run at its full load.

6. *Evidence of Actual Fires Caused Not Within Our Reach.*—As to the actual fires from the fuses, my clients are in no position to obtain information. They can only give a few samples obtained from a few factories operated by friends, who were willing to allow their fuses to be examined. All four of my clients have found cases of the destruction of Economy fuses by charring and of the misuse of Economy fuses by improper refilling, and I am about to send along a few samples of such improper use. I am aware that the time given by the Bureau for this purpose has expired, but Dr. Rosa stated at the hearing in July that no technical rules would be observed, and I am sending the fuses in question as promptly as possible, although they are only illustrative of dangers which are obvious.

The question before the Bureau is whether the Economy company has made good its case, that its fuses are not a greater fire hazard than the approved fuses, and practically, the question is whether the Underwriters have properly exercised their right to refuse at present to approve the Economy fuse. We submit that the Economy fuse has completely failed to meet the Underwriters' objections, which may be formulated substantially as follows:

1. The Economy fuse *can not* be made so as to meet the long-established short-circuit tests which properly designed and made fuses readily meet. Occasional failures by approved fuse makers are accidents, and those fuses are always made to meet the requirements when any defect is found. The Underwriters are not bound to approve a fuse which can not be made to meet their requirements simply because certain approved fuses temporarily fall below those requirements.

2. Taken as a class, a very large percentage of the Economy fuses can not be run at their rated load, even for a trivial number of days, without being so weakened as either to fall to pieces, or fail on a very mild short circuit. This statement does not refer to fuses which fail on rating tests. The fuses which char from bad contact or misplaced links, etc., will frequently rate properly. It is a fundamental danger of the Economy fuse, owing to the nature of the contact made for the purpose of making it readily refillable.

3. The fact that the Economy fuse is designed to be refilled by the user is a grave danger.

(*a*) The user can not be relied upon to insert the link accurately, and bad contacts, charring, and other troubles are likely in consequence.

(*b*) Overfusing is encouraged, as two links may readily be put in for one by the most unskillful operator and are so put in.

(*c*) The user, desiring to save, and not being the one who has to pay the fire loss, will use the charred and weakened cases, which, in a short time will be the most marked feature of the Economy fuse in actual use, as none will be thrown away until they have reached that condition.

It has been suggested that the Underwriters' tests are absurdly severe. The answer is: They have been long in use, they are readily met by properly designed fuses, which can be put on the market for less than one-third of the cost of the Economy fuses, and the public should not be encouraged to use a fuse which can not meet those requirements, when a fuse which can is on the market, selling for one-third its cost.

Moreover, the Underwriters have not asked the Bureau whether the tests are too severe. It is sufficient that a short circuit as bad is possible in use, and that under such circumstances the approved type of fuse can readily be made to meet the tests and can confidently be expected to do so, while the Economy fuse stands at least a 33⅓ per cent chance of going wrong when new and may be confidently expected to do so if it has been in use any length of time.

It is also suggested that as two fuses are usually used in series, the Underwriters' practice of testing the fuse singly is wrong. To this there are two obvious answers.

First. To determine the quality of a fuse, it must be tested alone.

Second. Fuses are not by any means always used in series. In many circuits one fuse has to bear all the burden, and the idea that the resistance of a grounded circuit is necessarily high is erroneous.

It has been suggested that certain plants using many motors rely upon their fuses to protect their apparatus and blow out each fuse on an average once a day, and that it is a great burden to them to be asked to buy a nonrefillable fuse. There are numerous answers to this suggestion. The first is—

That such plants are not legally prevented from using Economy fuses if they desire. The Underwriters merely refuse to approve such risks.

In the second place, it is a grossly erroneous practice to blow a fuse every day. It makes the cost of fuses, for each fuse, $5 or $6 a year or more, even for the small sizes,

and in such cases a circuit breaker should be installed, which will operate without danger to the Underwriters. A circuit breaker can be bought for $9, which will save its cost in two years' use on such a circuit on fuses alone, and will save far more than its cost in one year in saving of time of operatives. Underwriters should not be asked to approve a defective type of fuse simply for exceptional cases of stupid management.

In the third place, the point is immaterial. If the fire or accident risk from a poor type of fuse, intended to be used until it burns, is greater, the arbitration must be decided against the Economy fuse, regardless of convenience to the user. The question of convenience is not before the Bureau.

7. *Misuse of Approved Fuses.*—The Bureau has found that in many cases fuses listed as approved have been refilled by the user, or by an unauthorized maker, or otherwise wrongfully used. Such fuses have ceased to be approved fuses, and the Bureau has no right to determine this arbitration on its view of the question whether the approved fuse is more likely to be misused than the Economy fuse. The Economy fuse can be misused and frequently is misused, as I have seen in many cases. The aggregate number of approved fuses being much greater than Economy fuses, the aggregate number of cases of misuse of approved fuses would naturally be expected to be greater. Furthermore, the Economy fuses have not been approved, and the Underwriters have permitted their use only in specially selected factories, so that the percentage of misuse ought to be very small. In point of fact, however, the misuse of an Economy fuse is by no means unusual, as I know from personal experience. Nevertheless, the Underwriters do not approve misused fuses. Whether formerly approved, or whether of the Economy type, they are ordered out when seen. They have a right to approve only fuses which will meet their tests and avoid a fire hazard when properly used, and they can not be required to approve a dangerous fuse, simply because good fuses are sometimes the victim of misuse of fuses, any more than they can be required to approve inflammable conditions, because some persons set fires deliberately. In any case, the Bureau has not been asked to determine the dangers from misuse, but only the comparative danger of the Economy fuse and the approved fuse.

8. *Comparison of Economy and Approved Fuses.*—A brief comparison of Economy and approved fuses in parallel columns is shown on pages 197 to 199.

9. *Idea of Fuse Refillable by the User Fundamentally Wrong.*—It can not be too strongly stated that the whole principle of putting out a fuse refillable by the user is wrong. The Underwriters have for 10 years worked upon the principle that they would only approve fuses bearing the label of a person responsible for their manufacture or refilling. For the past 10 years the label of the responsible manufacturer of a fuse not showing outward signs of tampering, has been a symbol to the Underwriters that almost perfect safety from fire existed with regard to such fuses.

If, now, fuses refillable by the user are approved, the label of the manufacturer has no meaning whatsoever, so far as fire risk is concerned. The inspector may think the fuse was correct when it left the maker's factory, but of what has happened to it since he has no knowledge. Every elevator boy or stock-room boy is an approved manufacturer of fuses, and it is inconceivable to the manufacturers of approved fuses that such a system of manufacture of fuses can be said to have been proved as safe as the present system. It is useless to elaborate this matter further. It is a matter which speaks for itself, and all the evidence of misuse of approved fuses only tends to accentuate the injustice of forcing the Underwriters to approve fuses in effect manufactured by the people who so misuse fuses.

Not the least of the deplorable results following from the approval of fuses refillable by the user, is the fact that it removes all responsibility for fuses from any one. The tests at Chicago and Boston show that a properly made and designed fuse is absolutely perfect, but, also, that any shop carelessness will result in a small percentage of defects.

If fuses refillable by the user are approved, no manufacturer will have any serious incentive to keep up his product, because he can readily, in case of fire, hide behind the excuse that the fuse was probably refilled by the user.

10. *Conclusions.*—On the whole case, I contend that the Economy Fuse & Manufacturing Co. has completely failed to show that the use of the fuses manufactured by it results in no greater fire or accident hazard than the use of other cartridge-inclosed fuses, at present listed as standard by the Underwriters' Laboratories. On the contrary—

First. The Economy fuse has been proved to be a greater fire and accident hazard on short-circuit tests which have been prescribed by the Underwriters and met by the approved fuses for many years.

Second. The Economy fuse, owing to its construction, inevitably deteriorates rapidly in strength of fiber and in many cases smolders near the end cap and chars or burns up so as to constitute a serious fire hazard, by reason of bad contact, bad placing of link, bad threading, and many other causes (not all of which are known).

Third. The Economy fuse tempts to overfusing and makes such overfusing very convenient.

All the foregoing difficulties are due to the endeavor of the Economy company to make its fuses readily refillable by the user. A fuse refillable by the user is inevitably dangerous, as a user can not be trusted to do refilling, and will inevitably use the fuse until it burns up or is otherwise destroyed.

The extent of the danger as to any one fuse is undoubtedly slight, but on questions of insurance, where the rate is frequently much less than 1 per cent so that an entire plant must operate without serious fires for 50 or 100 years, in order to save the Underwriters from a net loss, it is the exceptional case which is to be considered.

The refilling of fuses by the user is fundamentally wrong. It is absurd to say that 200,000 anonymous approved manufacturers are not a greater fire hazard than a few thoroughly competent makers putting out fuses under their own label, for which they are responsible.

Furthermore, the extent of excess of danger by the use of the Economy fuse is not material. The Bureau must decide against the Economy fuse, unless that company has *proved* that its use results in *no* greater fire or accident hazard than the approved fuses. The contrary is the case, and accordingly, the arbitration should be determined against the Economy fuse.

GUY CUNNINGHAM,
(Attorney for D. & W. Fuse Co., Johns-Pratt Co., Chase-Shawmut Co., and the Bryant Electric Co.)

11. *Subscript to Mr. Cunningham's Statement.*—Why fire hazard of Economy fuses is greater than fire hazard of standard approved fuses.

ECONOMY FUSES	APPROVED FUSES
1. Can not meet Underwriters' long-established requirements as to short-circuit tests. Failure is due to fundamentally faulty design.	1. Are readily made to meet Underwriters' requirements. Failures indicate only lapses from perfection, readily corrected.
2. Opens the circuit too quickly, causing—	2. Opens the circuit as slowly as desired.
(*a*) Inductive kick, raising voltage to degree dangerous to apparatus.	(*a*) Inductive kick kept within safe bounds.
(*b*) Blowing too quickly on momentary overload.	(*b*) Blowing may be as sluggish as desired.
Defect fundamental. The too quick action is necessary to prevent nonfilled Economy fuses exploding.	Standard fuses may be made to operate as desired in the above matter, as filler gives large margin of safety.

3. Lack of filling and other features result in dangerous oscillations before circuit is finally opened.	3. Practical absence of dangerous oscillations.
4. Cutting thread in fiber fundamental error.	4. Fiber not threaded.
(*a*) Fiber is made in layers, adhesion of which is destroyed by heat or dryness.	(*a*) Cap is bolted through fiber, giving permanent hold.
5. Contact dependent on threaded joints unreliable.	5. Contacts soldered; no reliance on threaded contact.
6. Deteriorates rapidly.	6. Deteriorates slowly.
(*a*) Fiber chars and loses strength, particularly at threads, in large proportion of cases, whenever fuses run at full load.	(*a*) Charred fiber very rare, even when fuses run at full load.
(*b*) Screw contacts work loose.	(*b*) Soldered contacts permanent.
(*c*) Strength of fiber vital	(*c*) Filler makes strength of casing less important.
7. Refilling by user encouraged, leading to errors causing fire hazards.	7. No refilling of ferrule type. No refilling by user of any type authorized or instructions given.
(*a*) User likely to refill with poor contact.	(*a*) Maker solders contact. There is no question of screwing up complete contact.
I. Failure to scrape contacts.	
II. Failure to screw up end cap tight, thread being frequently clogged after fuse has blown.	
(*b*) User likely to get parts in knife-blade type wrong side before, resulting in wrong alignment of blades and space for escape of flame between washers.	(*b*) No such complication in approved fuses.
(*c*) User likely to insert link wrongly, so that it will char fiber case.	(*c*) No such danger as to approved fuses.
(*d*) Refilling by homemade link likely—	
I. Causing unintentional overfusing.	
II. Causing heat when link used has high melting point.	
8. Overfusing simple and probable.	8. Overfusing difficult and less likely.
(*a*) Economy tempts to overfusing by blowing on momentary surge. (See oscillograms.)	(*a*) Standard fuses more sluggish. Do not blow on so short surge.
(*b*) Economy company supplies two links with each fuse, making overfusing simple.	(*b*) No extra links supplied.
(*c*) Use of two links not discoverable except by taking fuse apart.	(*c*) Tampering with fuse more apparent.
(*d*) Filling with copper wire or strip of iron can be done in a moment without leaving machine.	(*d*) *Refilling* a slow job, requiring special tools.
(*e*) Bridging fuse terminals with wire possible. This, however, is not easier than bridging cut-out terminals.	(*e*) Bridging terminals with wire possible. This, however, is not easier than bridging cut-out terminals.
(*f*) User tempted to overfuse to prevent frequent refilling.	(*f*) Maker will not overfuse.

(*g*) User tempted to overfuse by home-made link, when correct link mislaid, or out of stock, or considered expensive.

(*h*) Refilling of charred or weakened casing likely. Charred or weakened cases probable.

(*g*) Maker uses correct link. Refilling by user by homemade link usually obvious.

(*h*) Makers' experts always warned to discard weakened fiber. Weakened fiber not usual in filled fuses.

IX. SUMMARY

The evidence presented in detail in the foregoing report has been carefully studied and weighed by the representatives of the Bureau of Standards, and has led to the conclusion that further experience with the Economy fuse under service conditions is desirable before it should be approved by Underwriters' Laboratories for unrestricted use. A detailed summary of all of the evidence presented above has been set forth in Section I of this report, and the finding of the Bureau of Standards in the case is given at the end of that summary.

WASHINGTON, February 14, 1916.

OSCILLOGRAPH RECORDS OF TYPICAL FUSE TESTS, SHOWING RELATIONS OF CURRENT, VOLTAGE, AND TIME

42812°—16——14

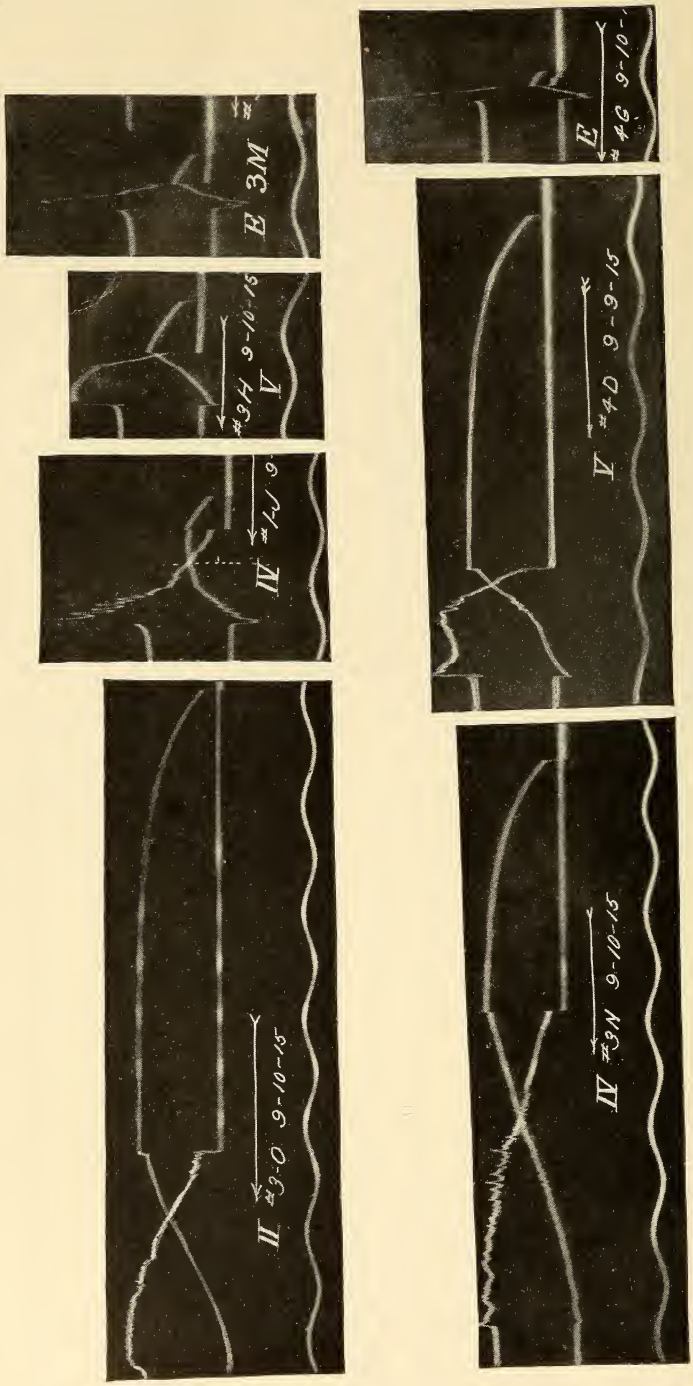

FIG. 1

Description of Fuses and Test Conditions for Oscillograms Shown in Fig. 1

Film	Volts	Amperes	Fuse No.	Circuit resistance in ohms	Inductance in millihenrys	Voltage rise in per cent	Maximum current in amperes	Energy input in kw.-sec.
3–O	250	400	II	0. 025	0. 186	120	9060	42. 5
1–J	250	100	IV	. 025	. 186	262	4725	11. 7
3–H	250	100	V	. 025	. 186	188	5520	8. 6
3–M	250	60	Economy	. 025	. 186	300	4130	3. 1
3–N	250	400	IV	. 025	. 186	120	9445	34. 7
4–D	250	400	V	. 025	. 186	160	9450	25. 5
4–G	250	30	Economy	. 025	. 186	264	3150	2. 7

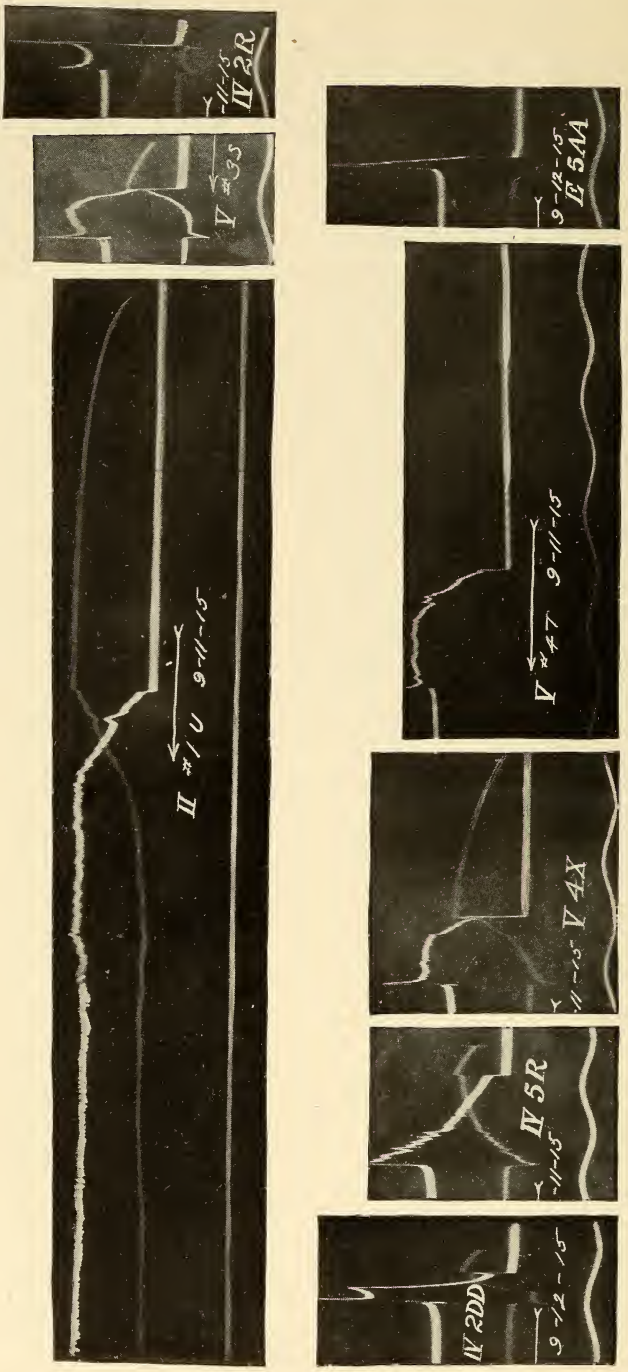

FIG. 2

Description of Fuses and Test Conditions for Oscillograms Shown in Fig. 2

Film	Volts	Amperes	Fuse No.	Circuit resistance in ohms	Inductance in millihenrys	Voltage rise in per cent	Maximum current in amperes	Energy input in kw.-sec.
3–S	250	100	V	0.025	0.110	200	6300	9.6
2–R	250	30	IV	.025	.110	233	4725	2.0
2–DD	250	60	IV	.025	.110	255	6300	3.8
5–R	250	100	IV	.025	.110	200	5900	10.2
4–X	250	200	V	.025	.110	190	8660	14.1
4–T	250	400	V	.025	.110	141	9450	22.7
5–AA	250	30	Economy	.025	.110	266	4725	1.1

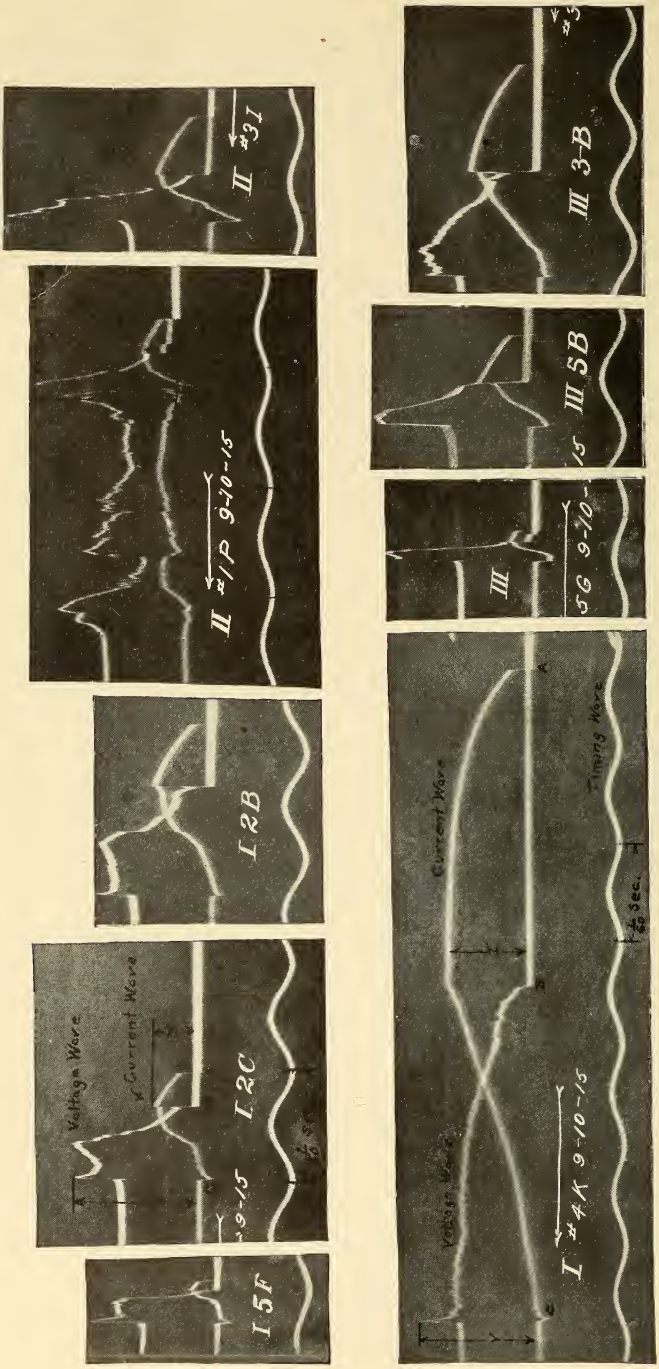
Voltage Wave
Current Wave
I 15F
I 12C
I 12B
II #1P 9-10-15
II #3I
I #4K 9-10-15
III 5G 9-10-15
III 5B
III 3-B

FIG. 3

Description of Fuses and Test Conditions for Oscillograms Shown in Fig. 3

Film	Volts	Amperes	Fuse No.	Circuit resistance in ohms	Inductance in millihenrys	Voltage rise in per cent	Maximum current in amperes	Energy input in kw.-sec.
5–F	250	30	I	0.025	0.186	166	3150	2.0
2–C	250	100	I	.025	.186	158	4750	7.6
2–B	250	200	I	.025	.186	150	6700	14.2
1–P	250	60	II	.025	.186	183	3940	16.8
3–I	250	100	II	.025	.186	258	6300	8.4
4–K	250	600	I	.025	.186	150	10 240	40.1
5–G	250	30	III	.025	.186	200	3150	1.6
5–B	250	100	III	.025	.186	210	5520	6.6
3–B	250	200	III	.025	.186	150	7875	17.6

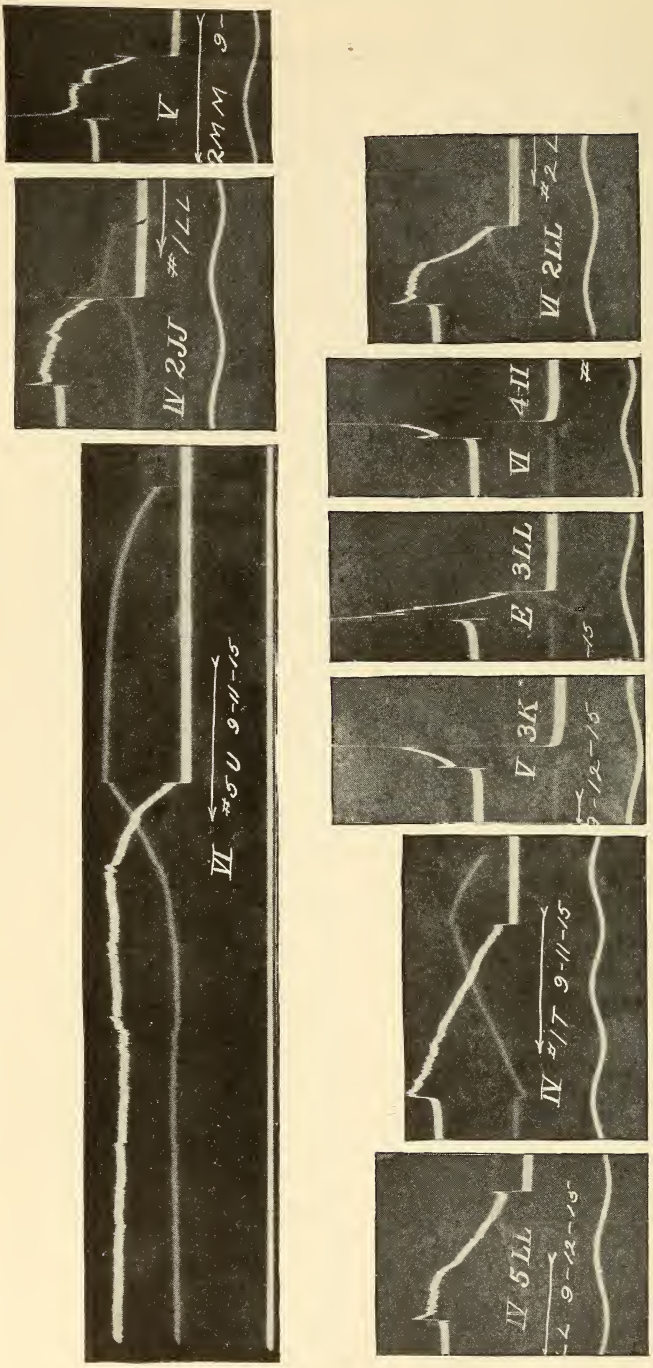

FIG. 4

Description of Fuses and Test Conditions for Oscillograms Shown in Fig. 4

Film	Volts	Amperes	Fuse No.	Circuit resistance in ohms	Inductance in millihenrys	Voltage rise in per cent	Maximum current in amperes	Energy input in kw.-sec.
5–U	250	600	VI	0.025	0.110	100	9450	65.1
1–LL	250	100	III	.040	.166	154	4725	8.0
2–MM	250	100	V	.040	.166	219	4730	4.3
5–LL	250	100	IV	.040	.166	145	4330	10.0
1–T	250	200	IV	.025	.110	145	7875	20.9
3–K	250	600	V	.025	.186	138	5900	68.6
3–LL	250	60	Economy	.040	.166	308	3940	3.4
4–II	250	30	VI	.040	.166	310	3545	1.2
2–LL	250	100	VI	.040	.166	165	4330	7.0

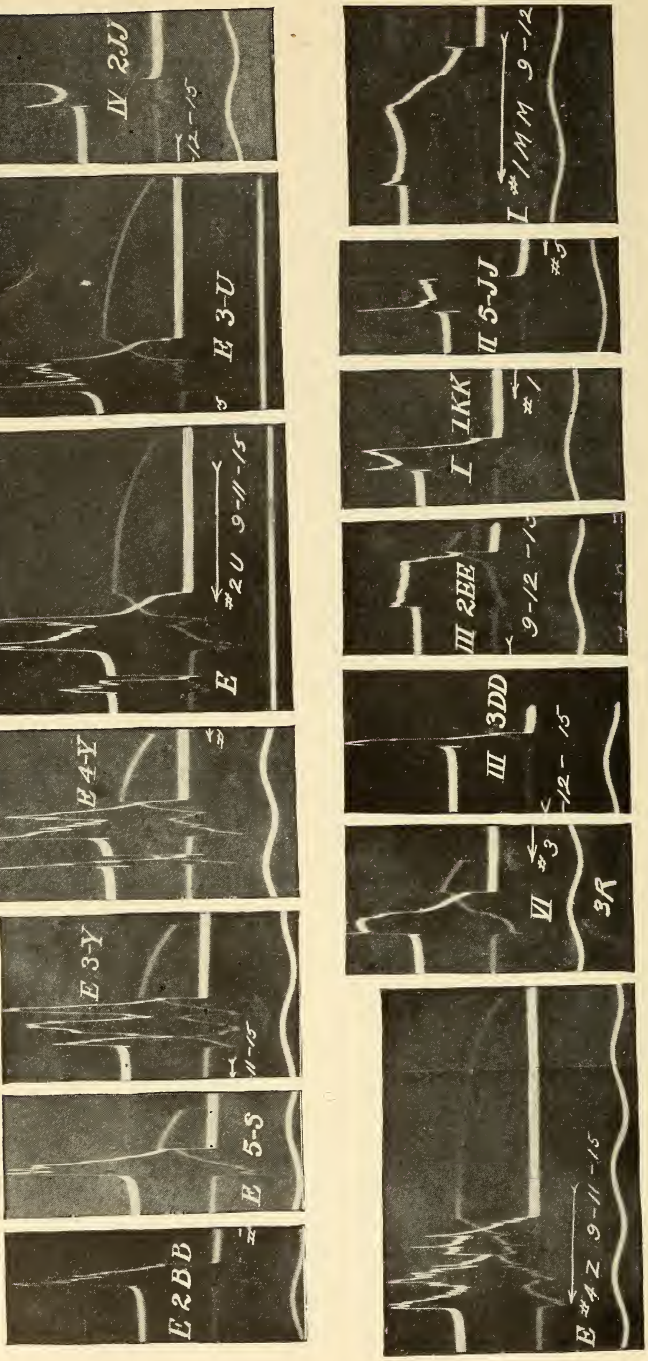
E 2BB
E 5-S
E 3-Y
E 4-Y
E
E 3-U
IV 2JJ
E #4 Z 9-11-15
VII #3 3R
III 3DD 12-15
III 2EE 9-12-15
I 1KK #1
II 5-JJ #3
I #1 MM 9-12

FIG. 5

Description of Fuses and Test Conditions for Oscillograms Shown in Fig. 5

Film	Volts	Amperes	Fuse No.	Circuit resistance in ohms	Inductance in millihenrys	Voltage rise in per cent	Maximum current in amperes	Energy input in kw.-sec.
2–BB	250	60	Economy	0.025	0.110	266	6675	3.0
5–S	250	100	.....do	.025	.110	271	6300	5.3
3–Y	250	200	.....do	.025	.110	266	7480	8.2
4–Y	250	200	.....do	.025	.110	283	7480	8.2
2–U	250	900	.....do	.025	.110	316	9250	15.0
3–U	250	400	.....do	.025	.110	310	8860	15.0
2–JJ	250	30	IV	.040	.166	242	3545	1.3
4–Z	250	600	Economy	.025	.110	200	9450	19.6
3–R	250	100	VI	.025	.110	200	5900	5.6
3–DD	250	30	III	.025	.110	250	5120	1.1
2–EE	250	60	III	.025	.110	133	5515	4.4
1–KK	250	30	I	.040	.166	175	3150	.9
5–JJ	250	30	II	.040	.166	250	3940	1.9
1–MM	250	100	I	.040	.166	133	3940	5.2

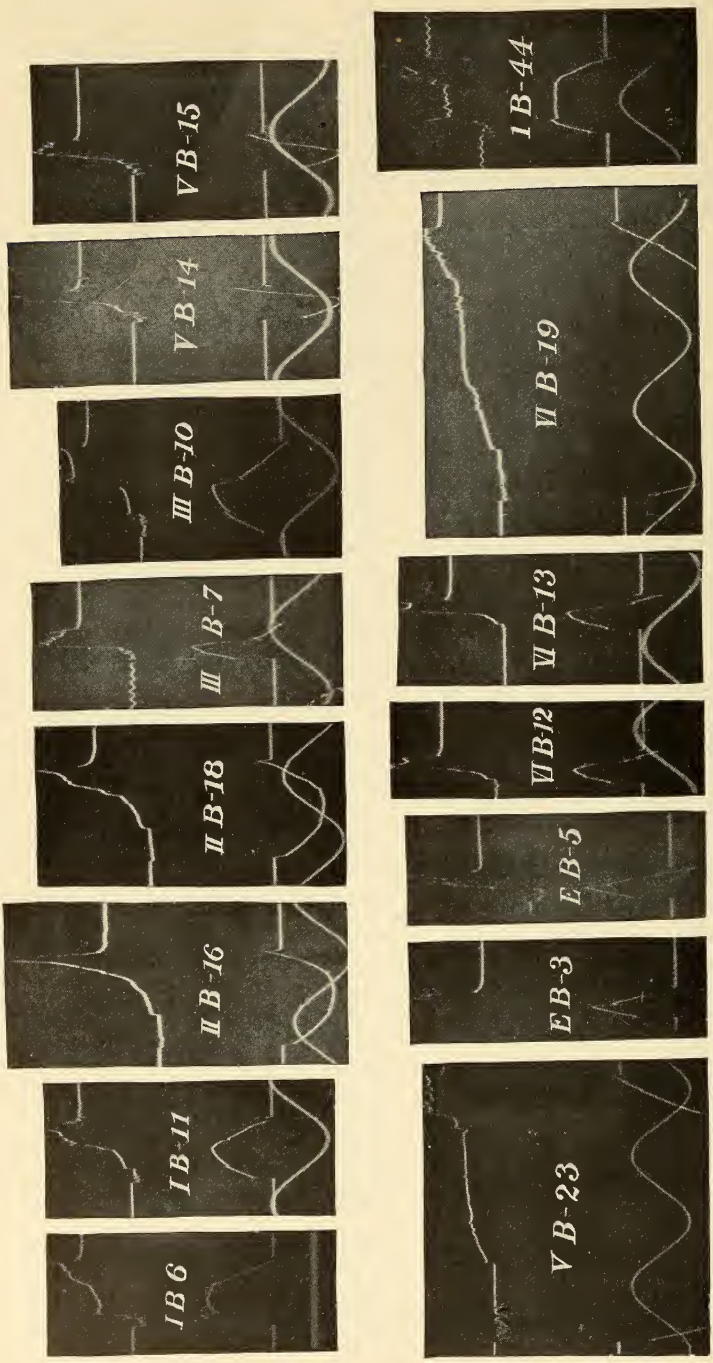
I B 6
I B-11
II B-16
II B-18
III B-7
III B-10
V B-14
V B-15
V B-23
E B-3
E B-5
VI B12
VI B-13
VI B-19
I B-44

FIG. 6

Description of Fuses and Test Conditions for Oscillograms Shown in Fig. 6

Film	Volts	Amperes	Fuse No.	Circuit resistance in ohms	Inductance in millihenrys	Voltage rise in per cent	Maximum current in amperes	Energy input in kw.-sec.
B–6	600	30	I	0. 06–0. 033	0. 210	100	4420	10. 2
B–11	600	60	I	. 06– . 033	. 210	300	.....	11. 8
B–16	600	100	II	. 06– . 033	. 210	300	9590	0. 5
B–18	600	100	II	. 06– . 033	. 210	248	9470	0. 5
B–7	600	30	III	. 06– . 033	. 210	220	5030	.....
B–10	600	60	III	. 06– . 033	. 210	170	8500	15. 5
B–14	600	30	V	. 06– . 033	. 210	267	4880	2. 1
B–15	600	30	V	. 06– . 033	. 210	200	4720	4. 3
B–23	600	200	V	. 06– . 033	. 210	155	6100	.....
B–3	600	30	Economy	. 06– . 033	. 210	180	5180	4. 0
B–5	600	30	.....do	. 06– . 033	. 210	160	5180	3. 7
B–12	600	30	VI	. 06– . 033	. 210	200	4270	.....
B–13	600	30	VI	. 06– . 033	. 210	225	4420	.....
B–19	600	200	VI	. 06– . 033	. 210	135	5480	3. 2
B–44	600	30	I	. 06	. 277	241	3410	8. 6

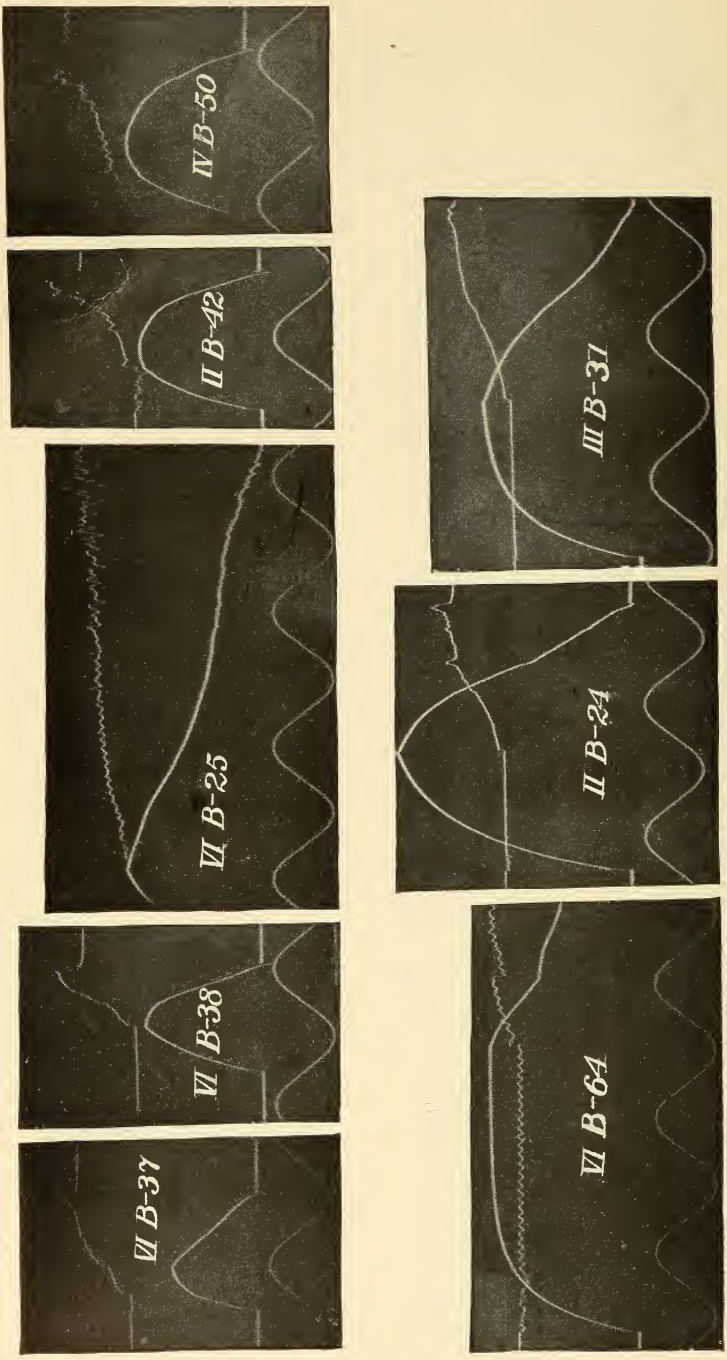

FIG. 7

Description of Fuses and Test Conditions for Oscillograms Shown in Fig. 7

Film	Volts	Amperes	Fuse No.	Circuit resistance in ohms	Inductance in millihenrys.	Voltage rise in per cent	Maximum current in amperes	Energy input in kw.-sec.
B–37	600	60	VI	0.06	0.277	210	5180	12.8
B–38	600	100	VI	.06	.277	230	6800	10.7
B–25	600	200	VI	.06	.277	168	8230	62.0
B–42	600	100	II	.06	.277	257	7310	16.0
B–50	600	100	IV	.06	.277	235	6860	19.3
B–64	600	400	VI	.06	.277	75	8980	143.6
B–24	600	200	II	0.06– .033	.210	148	14330	21.4
B–31	600	200	III	.06	.277	117	9380	21.4

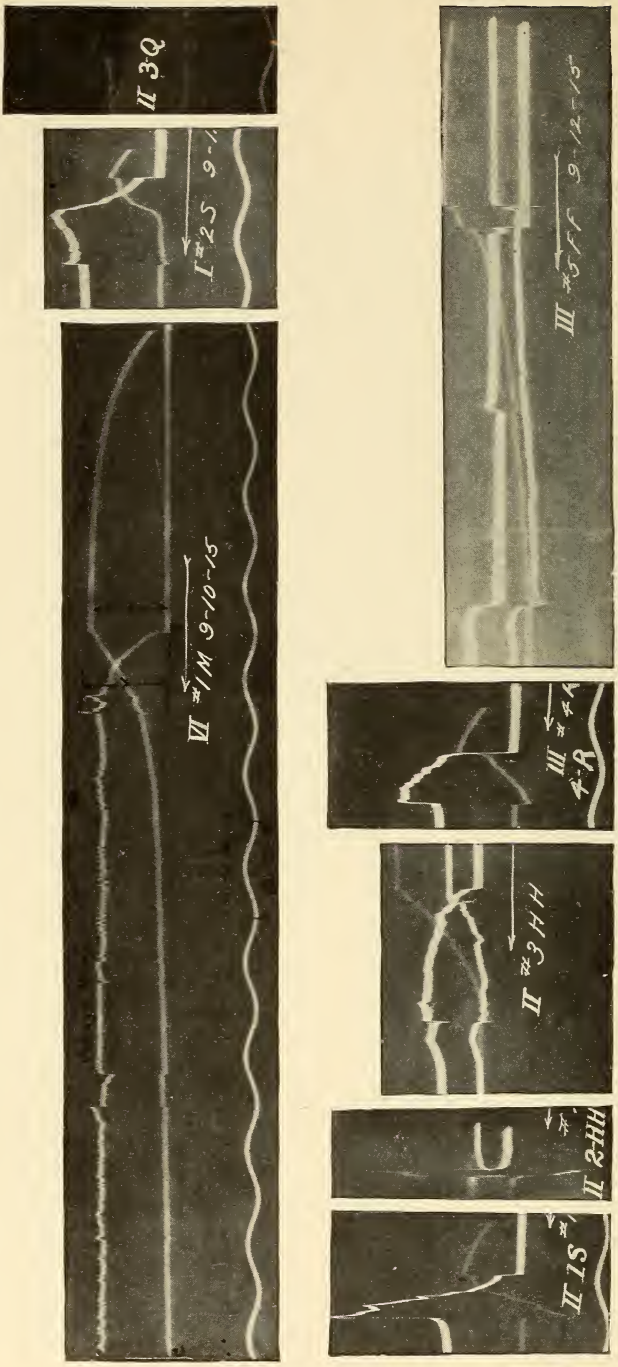

FIG. 8

428128°—16——15

Description of Fuses and Test Conditions for Oscillograms Shown in Fig. 8

Film	Volts	Amperes	Fuse No.	Circuit resistance in ohms	Inductance in millihenrys	Voltage rise in per cent	Maximum current in amperes	Energy input in kw.-sec.
1–M	250	600	VI	0.025	0.186	113	9060	56.0
2–S	250	100	I	.025	.110	130	5515	8.4
3–Q	250	30	II	.025	.110	250	4725	2.3
1–S	250	100	II	.025	.110	250	6300	7.7
2–HH	250	30	II	.025	.110	435	4725	A= 0.4 B= 0.5
3–HH	250	400	II	.025	.110	133	9450	A=14.0 B= 9.7
4–R	250	100	III	.025	.110	155	6300	7.2
5–FF	250	400	III	.025	.110	135	10240	A=15.2 B=18.3

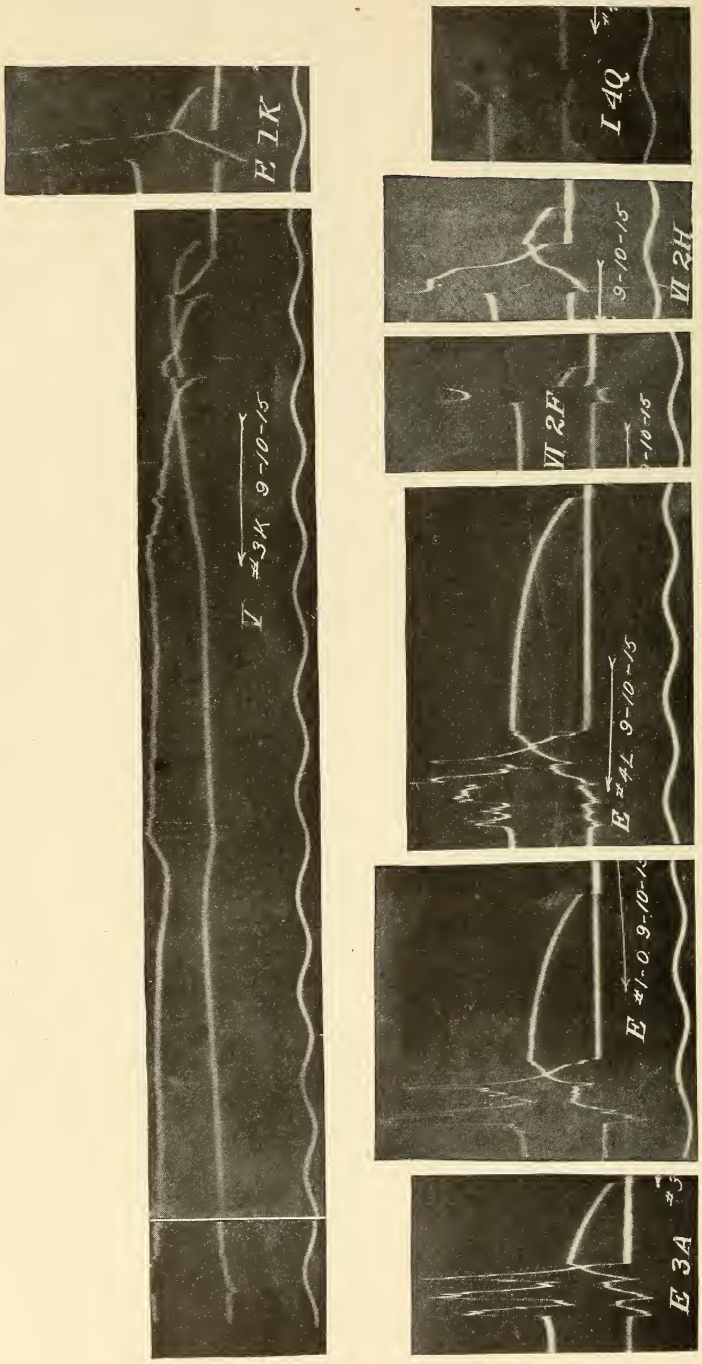

FIG. 9

Description of Fuses and Test Conditions for Oscillograms Shown in Fig. 9

Film	Volts	Amperes	Fuse No.	Circuit resistance in ohms	Inductance in millihenrys	Voltage rise in per cent	Maximum current in amperes	Energy input in kw.-sec.
3–K	250	30	V	0.040	0.166	300	3150	1.0
1–K	250	100	Economy	.025	.186	275	5520	5.7
3–A	250	200	.....do	.025	.186	266	7450	10.5
1–O	250	400	.....do	.025	.186	310	8450	15.9
4–L	250	600	.....do	.025	.186	235	9950	19.6
2–F	250	30	VI	.025	.186	295	3940	2.3
2–H	250	100	VI	.025	.186	227	5120	7.0
4–Q	250	30	I	.025	.110	150	4725	1.3

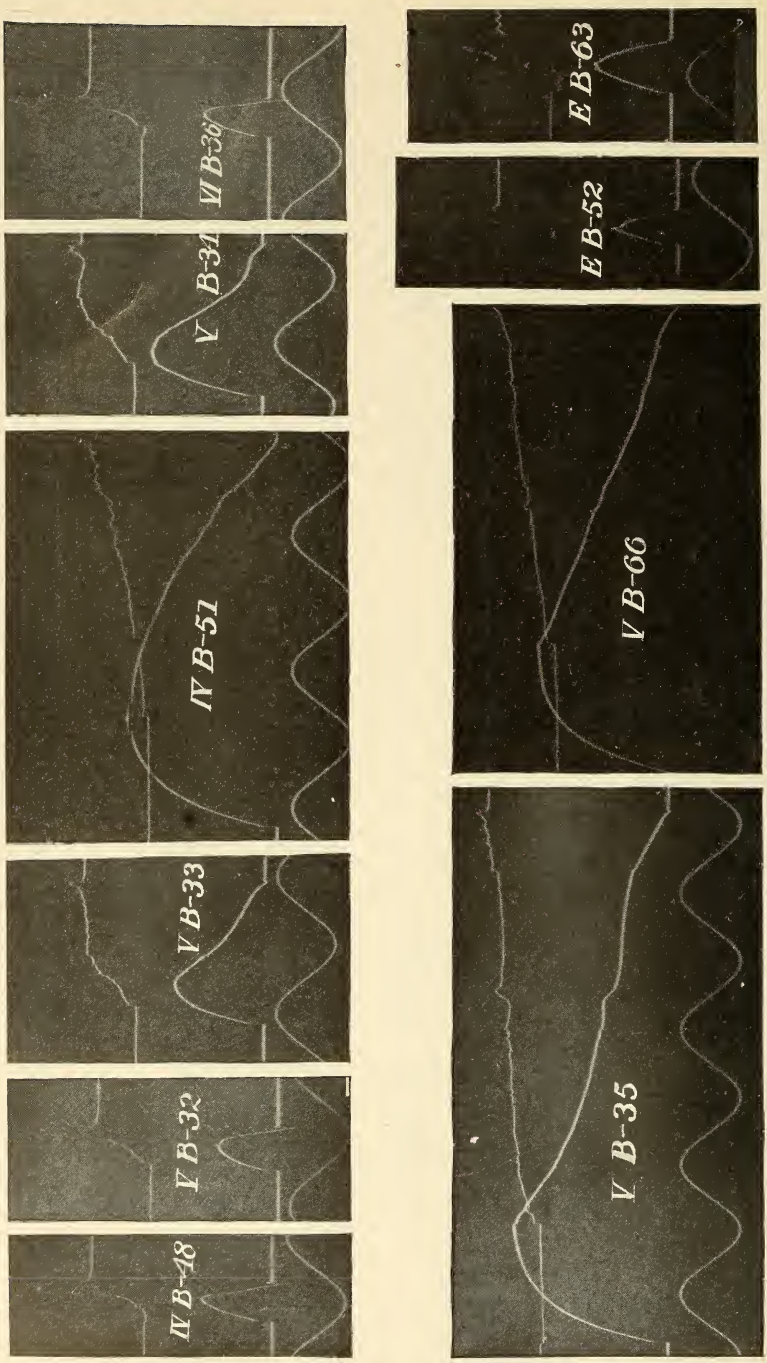

FIG. 10

Description of Fuses and Test Conditions for Oscillograms Shown in Fig. 10

Film	Volts	Amperes	Fuse No.	Circuit resistance in ohms	Inductance in millihenrys	Voltage rise in per cent	Maximum current in amperes	Energy input in kw.-sec.
B–48	600	30	IV	0.06	0.277	272	4270	3.2
B–32	600	30	V	.06	.277	270	3660	3.2
B–33	600	60	V	.06	.277	130	5360	15.0
B–51	600	200	IV	.06	.277	120	9050	32.1
B–34	600	100	V	.06	.277	130	6610	17.1
B–36	600	30	VI	.06	.277	310	3900	3.2
B–35	600	200	V	.06	.277	128	9350	56.6
B–66	600	200	V	.06	.277	123	8520	46.5
B–52	600	30	Economy	.06	.277	290	3960	3.7
B–63	600	60	.....do	.06	.277	260	4570	5.9

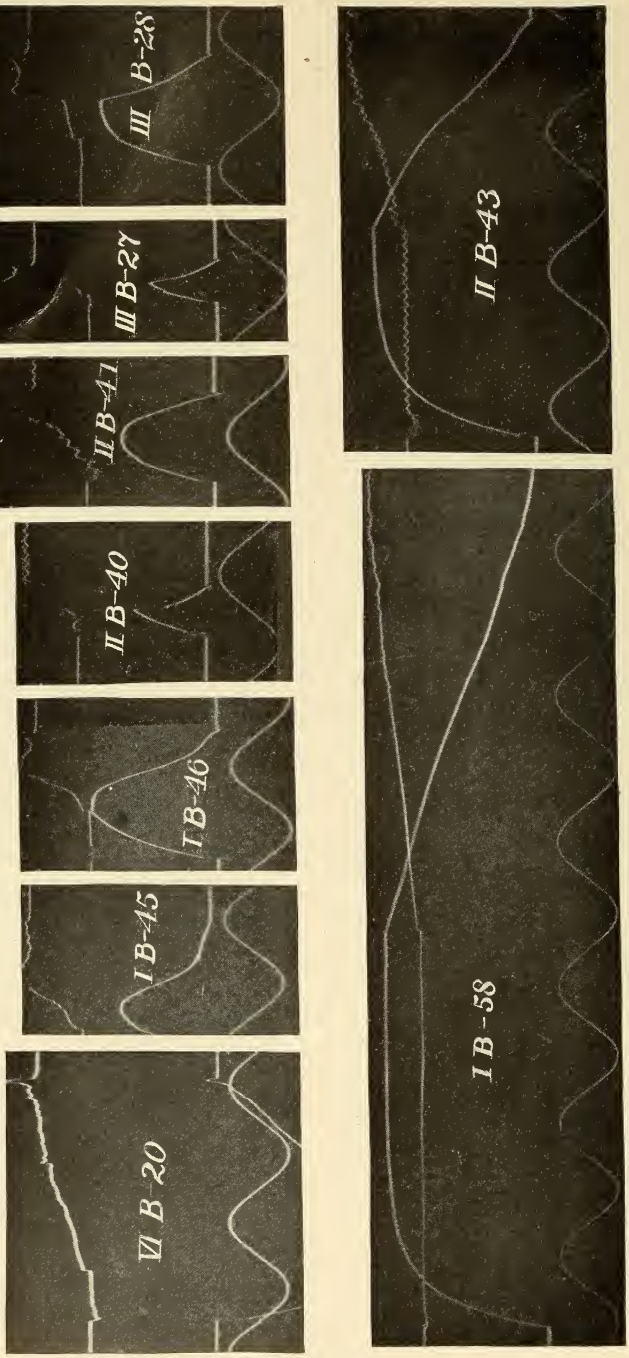

FIG. 11

Description of Fuses and Test Conditions for Oscillograms Shown in Fig. 11

Film	Volts	Amperes	Fuse No.	Circuit resistance in ohms	Inductance in millihenrys	Voltage rise in per cent	Maximum current in amperes	Energy input in kw.-sec.
B–20	600	200	VI	0. 06–0. 033	0. 210	170	6100	3. 2
B–45	600	60	I	.06	.277	130	5400	11. 8
B–46	600	100	I	.06	.277	140	7560	12. 8
B–40	600	30	II	.06	.277	200	4420	4. 3
B–41	600	60	II	.06	.277	200	5560	9. 6
B–27	600	30	III	.06	.277	174	4020	4. 3
B–28	600	60	III	.06	.277	145	6460	15. 0
B–58	600	400	I	.06	.277	100	9570	73. 9
B–43	600	200	II	.06	.277	124	9560	23. 5

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